Puget Sound Research 2001

The Puget Sound/Georgia Basin Ecosystem:
Status, stressors and the road to recovery

Abstracts of Poster Presentations

POSTER PRESENTATIONS

Table of Contents

POSTER GROUP A: ECOLOGICAL MODELING AND ASSESSMENT

The Decline of Herring at Cherry Point, Washington

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The stock of herring (*Clupia pallasi)* which spawns in the vicinity of Cherry Point (near Bellingham) once was the largest stock of herring in Washington. The stock has shown a dramatic decline of 95 percent in recent years and is now at an unprecedented low level of abundance. There are several potential explanations for the decline including increased mortality of adult herring, decreased hatching success, changes in the offshore environment and degraded spawning habitat.

Results from recent studies by the University of Washington indicate the herring eggs deposited near Cherry Point have low hatching success and high rates of abnormal development. Those larvae which do hatch successfully are very small compared to larvae from other areas.

The spawning habitat at Cherry Point is also the site of major industrial activity. Several industries utilize the spawning area and there are plans to expand the existing facilities and add new facilities in the near future. There is a growing need to ensure that the industrial activities are not contributing to the decline of herring in the area. To address the issue, representatives from several state agencies (Fish and Wildlife, Ecology and Natural Resources) and affected industries has been meeting regularly to design studies and evaluate the results.

Next year will be important for the future of the herring stock. Another year of poor adult returns will drive the stock to the brink of extinction. The Department of Natural Resources will decide on issuing leases for expanded industrial activity at Cherry Point.

An Integrated Molecular Biomarker System to Assess and Compare the Health of Aquatic Life in Washington State Waters

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We are conducting field and laboratory studies to validate the utility of cellular biomarkers in assessing coastal ecosystem health. Several species of marine invertebrates are being collected along a gradient of anthropogenic inputs extending from the pristine outer coast of Washington, through the Strait of Juan de Fuca and into Puget Sound. Within Puget Sound, samples are being collected from both commercial areas and fish habitats with known or suspected gradient of anthropogenic insult. Cellular biomarkers, tissue residues and environmental stressors will be assessed to determine if they are predictive of the gradient in stressors and predictive of one another.

Biomarker analysis will be conducted using the *Downs Molecular Biomarker System*™ (MBS). MBS uses an integrated suite of 10-15 molecular biomarkers to detect physiological changes at a subcellular level to assess an organisms health. The biomarkers include general indicators of cell integrity (e.g., GSH, LPO and ubiquitin), molecular chaperones that gauge the integrity of enzyme pathways (Hsp 60 & 70), small heat shock proteins produced in response to heat stress and other insults (αB-crystallin, Hsp22, Hsp26 and Hsp30), anti-oxidant enzymes indicative of oxidative stress (MnSOD and Cu/ZnSOD), and indicators of xenobiont exposure (cytochrome P450) and metal stress (metallothionein).

Summary of Major Findings from the U.S. Geological Survey National Water-Quality Assessment Program in the Puget Sound Basin

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U.S. Geological Survey

Small streams and large rivers in the Puget Sound Basin met most Federal and State water-quality guidelines, but there were exceptions. The insecticide diazinon, commonly used by homeowners on lawns and gardens, was frequently detected in urban streams at concentrations that exceeded guidelines for protecting aquatic life, and levels of *E. coli* bacteria were above USEPA criteria for moderate water-contact recreation in 15 of 31 small streams. Concentrations of total phosphorus were above the USEPA desired goal of 0.1 milligram per liter to prevent excessive plant growth in large rivers and small streams in agricultural and urban areas, but not in undeveloped areas. Streams in urban and agricultural areas were also warmer and supported less diverse populations of insects than streams in forested areas.

With some exceptions, ground water was of high quality. However, as indicated by elevated concentrations of nitrate and the presence of pesticides and other organic compounds, shallow ground water in both urban and agricultural settings is vulnerable to contamination. Deeper ground water is less affected by land-use activities. For example, pesticides were not detected in wells deeper than 120 feet, the depth below which most large public supply wells withdraw water.

Watershed Benefits of Environmental Monitoring Performed by a Medium-sized City

Melinda Fohn and Kathleen Cahall
City of Bremerton

Local government agencies perform environmental monitoring to fulfill requirements of permits and regulations. The City of Bremerton will describe the benefits of environmental monitoring to local watershed improvement projects.

Bremerton performs environmental monitoring for multiple programs including combined sewer overflows (CSOs), stormwater, drinking water, forestry and biosolids land application. Environmental monitoring data is used for both regulatory and investigative purposes.

Bremerton collects a variety of data including: water quality chemistry of stormwater, CSOs, groundwater and local streams; flow data of streams and CSOs; water level data of production and monitoring groundwater wells; soil, groundwater and stream chemistry of biosolids applied forest lands; and water chemistry, temperature, and stream morphology for the drinking water surface supply program.

Bremerton is able to provide local environmental data of high quality and is a participant in watershed studies and public education projects including: Puget Sound Naval Shipyard ENNVEST, 2514 Watershed Planning, Groundwater Guardians, Watersheds for Salmon, WaterPAK Water Conservation Task Force and the Kitsap Stormwater Consortium. The benefits and challenges of a medium-sized city's environmental monitoring program will be discussed.

Environmental monitoring data is managed in an access database which provides a means to query data and produce regulatory and internal reports.

A Watershed-based Ecological Risk Assessment for Sinclair Inlet, Washington

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The risk to ecological resources is being assessed at the watershed scale to develop and demonstrate an alternative strategy for protecting and improving the ecological integrity of Sinclair and Dyes Inlets. Through an agreement among the Puget Sound Naval Shipyard, the Environmental Protection Agency, and the Washington State Department of Ecology, the ecorisk process is being used to provide a unifying framework to focus data gathering activities, develop and incorporate concerns of agencies, organizations, or individuals that have a stake in the management of the watershed (stakeholders), foster partnering among stakeholders, and establish the technical and scientific basis to better protect and improve the health of the Inlets. The effects of stressors released from industrial and stormwater discharges, sewage treatment plants, and runoff from the surrounding watershed are being assessed by evaluating historical data, conducting studies to evaluate stressor sources and effects, and developing fate and transport models. The assessment will define the ecological state of the Inlets and surrounding watershed, establish a link between stakeholder values and assessment criteria, define management endpoints,

and develop a vision for the ecological health of the Inlets. Results from the assessment will help in addressing agency concerns and provide data to develop total maximum daily loading for priority constituents.

Environmental Trends in the Georgia Basin

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The State of the Environment Reporting Program provides the public as well as policy and decision-makers with data on environmental conditions and trends in the province. We present a selection of environmental indicators of the condition and trends in air quality, water quality, species diversity and habitat in the Georgia Basin. These indicators were developed using the following general criteria. Data are scientifically credible, relevant, representative and understandable to a non technical audience. Data will be available to allow updating of the indicator.

Overall results indicate that greater vigilance and continued efforts are needed to reduce air and water pollution. Excellent progress has been made to reduce disposal of domestic waste to landfills. Impacts from human activities including urban development, human disturbance, agriculture and logging threaten some species and 36 of 311 vertebrates species in the basin are listed as threatened or endangered. Of these 36, 7 are forest dwelling and dependent on riparian habitats. Finally as of 1999, 15 percent of the land area of the basin is set aside as protected areas. Details of these indicators are presented along with the status of actions to address these environmental concerns.

Patterns of Amphibian Use of Stormwater Ponds in King County

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University of Washington

Stormwater ponds are built to protect human health and safety as well as aquatic resources, primarily including wetlands and streams. Stormwater ponds are generally designed to detain stormwater and improve water quality, and may have unintended impacts on wildlife. A two-year study of 50 stormwater ponds in King County is being undertaken to determine the extent of use by amphibian species, whether mortality occurred prior to larvae metamorphosis due to pond drying, and if landscape and in-pond factors correlate with amphibian use. Pond age ranges from 1 to approximately 16 years. Preliminary results indicate that three species of caudates (Northwestern salamander—*Ambystoma gracile*, long-toed salamander—*A. macrodactylum*, rough-skinned newt—*Taricha granulosa*) and three species of anurans (red-legged frog—*Rana aurora*, bullfrog—*R. catesbeiana*, Pacific treefrog—*Hyla regilla*) breed in stormwater ponds. All ponds with standing water greater than 15 cm deep in March-April supported breeding amphibians. All species can colonize within two years of pond construction, and Pacific treefrogs colonized ponds in less than six months. Bullfrogs do not appear to exclude native amphibian species, and are occasionally present in temporarily flooded ponds. Northwestern salamander paedomorphs were observed in approximately 25 percent of ponds. Pacific treefrogs occurred most frequently, and rough-skinned newts were the least common of the six species observed. The Oregon spotted frog (*Rana pretiosa*) and Western toad (*Buffo boreas*) were not observed. Species richness appears to be positively correlated with the presence of forest within 100 meters of stormwater ponds. Fewer than five percent of ponds were observed to dry before larvae metamorphosis. Future work will examine the extent of egg stranding and correlations between water level fluctuations and species occurrence.

Puget Sound Mussel Watch—A Proposal for Integrated Biomonitoring

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Applied Biomonitoring

Several Puget Sound monitoring programs are designed to quantify the status and trends in ambient conditions using long-term monitoring approaches. A Puget Sound Mussel Watch program has been proposed to integrated to optimize the utility, comparability, and sharability of the data while minimizing costs associated with data collection. “Mussel Watch” is a monitoring approach that typically includes measuring tissue chemistry in resident or transplanted bivalves at regular intervals to establish the status and trends in environmental quality. The proposed approach would include measuring other endpoints such as biomarkers and growth to add an effects component to the monitoring. The addition of a Puget Sound Mussel Watch Program would provide a method to focus these programs on a more common goal, minimize the costs of data collection and maximize the consistency of the protocols. Other benefits to establishing a sound-wide Mussel Watch program include integration of existing programs with more cost- and services-sharing, consistency with the risk assessment methodology, more emphasis on using more tools in the environmental monitoring toolbox, and addition of previously under-utilized monitoring species. The purpose of this paper is to focus on rationale and methods for establishing a Puget Sound Mussel Watch Monitoring Program, and to make specific recommendations for implementation.

POSTER GROUP B: RIVERS, STREAMS AND WATERSHEDS

An Approach to Basin-Wide Impervious Area Measurement for Chinook Habitat Restoration

Chris Davis
CommEn Space

The restoration of naturally spawning Chinook populations in the Cedar/Sammamish watershed is a task complicated by the particularly unique features of this basin. The headwaters of the basin are within the protected bounds of the City of Seattle's water reservoir, while the Cedar's mainstem or passes through the sub-urbanized lowlands of King County before it drains through urbanized Seattle and into Puget Sound. Spawning and rearing Chinook must pass through Lake Washington, which at 22,000 surface acres in size, constitutes an unusual and potentially challenging habitat for Chinook. To support a basin wide recovery plan for Chinook, an evaluation of current land cover was conducted focusing primarily on measuring the extent of impervious surface area in each sub-basin using GIS and remote sensing techniques. This technique known as spectral mixing analysis (SMA), is an image analysis process that supports repeatable and accurate extraction of sub-pixel information. SMA differs from standard image classification approaches by measuring the comprising percentages of two "end-members" pixel by pixel, rather than classifying groups of pixels with similar spectral signatures into a given land cover typology. Further, using a combination of automated and manual GIS operations, additional data was developed from digital aerial photographs to measure built shoreline structures on Lakes Washington, Sammamish and Union. These data have been combined with Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP) data resulting in greater resources to support basin wide restoration planning by the Muckleshoot Tribe.

CEE-TV: Contaminant Exposure and Effects-Terrestrial Vertebrates Database

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The "Contaminant Exposure and Effects--Terrestrial Vertebrates" (CEE-TV) database summarizes contaminant exposure and effects information for free-ranging amphibians, reptiles, birds, and mammals residing within approximately 30 km of Atlantic, Pacific and Gulf coasts and estuarine ecosystems, including Alaska and Hawaii. Information is obtained by solicitation of unpublished reports from conservation agencies, resource managers, and scientists and from computerized searches of published literature and review of existing databases. The database can easily be queried using taxonomic, chronological, geographic, and contaminant search categories. Potential applications of the CEE-TV database include focusing biomonitoring efforts to generate critically needed ecotoxicological data for identified "gaps" along the coast; reducing uncertainty about contaminant risk; identifying areas for mitigation, restoration, or special management; and ranking the ecological conditions of estuaries. The CEE-TV database for Atlantic and Gulf coast estuaries is presently available on the World Wide Web (http://www.pwrc.usgs.gov/ceetv/). This database contains approximately 6000 records with ecotoxicological exposure and effects information on over 150,000 individuals representing over 250 species of amphibians, reptiles, birds, and mammals residing in Atlantic and Gulf coast estuaries. We are currently working on the Pacific Coast CEE-TV database. A preliminary CEE-TV database for Washington State is presented.

A Spatial Database for Big Beef Creek, Washington

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The purpose of this project was to establish a comprehensive spatial database for Big Beef Creek that would serve as a basis for future education and research activities at this site. Big Beef Creek, a salmon bearing stream, is located near Seabeck, Washington on Hood Canal. This small watershed encompasses about 38 square kilometers extending from the plateau of the Kitsap Peninsula through suburban development and forested land to productive tideflats on Hood Canal. University of Washington owns the lower 400 acres of the watershed and runs a fisheries field station at this site. The data compiled for this Geographic Information System (GIS) project includes Kitsap County vector coverages, a hydrological corrected Digital Elevation Model (DEM), and georegistration of multispectral imagery data at both 30 meter and one meter resolution. In addition to the raw data, this project also includes four useful project interfaces for examining the data, a lab journal to explain the methods used in creating the GIS archive, other supporting GIS metadata and a web interface to act as a user's guide in accessing the data. Spatial data is now readily available via the web and CD-ROM for use by students and researchers interested in using this field site. Sample data products will be presented.

Use of a Rotary Screwtrap to Monitor the Out-migration of Salmon Smolts from the Nooksack River: 1994–2000

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Lummi Natural Resources Department

This project seeks to establish a measure of baseline smolt production levels for the Nooksack River Basin by enumerating the out-migrating of salmon using a rotary screwtrap in the lower river mainstem. Watershed improvements that benefit salmon should result in an overall increase in smolt production when compared with these baseline measurements.

A single 8-foot diameter EGS rotary screw smolt trap was located 7.6 km from the river mouth. Except in 1994, we sampled from April 1 until the end of July. Since 1996 we have operated the screwtrap every other day during the sampling season. Starting in 1997 we sampled a standardized 6-hour set with start times of 0000, 0600, 1200, or 1800 hours as determined by a randomized schedule.

Seven seasons of operation has demonstrated that out-migrants can be non-lethally captured by the screwtrap, enumerated, measured, and sampled for scales and DNA tissues. Trap calibration studies using chinook smolts developed an approach for developing abundance estimates for all salmon species enumerated. Stock identification using DNA tissue samples has been demonstrated for chinook salmon. We developed an index of abundance for chinook to evaluate future smolt production levels that are anticipated following watershed restoration efforts.

Salmon in the Dungeness: How a Newspaper Insert Was Developed as a Watershed Educational Tool

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Jamestown S'Klallam Tribe

In 1999-2000 the Jamestown S'Klallam Tribe developed a 2-part newspaper insert focusing on salmon in the Dungeness watershed. Partially funded by an Environmental Protection Agency/Environmental Justice grant, the primary objective was to provide accurate information to the general public about salmon, and the Tribe's role in fisheries management. As the project developed, listings occurred of Dungeness and other Puget Sound chinook under the Endangered Species Act.

An editorial committee (Tribal Council member, natural resource staff, and public information specialist) shaped the content to meet rising interests in salmon/ESA issues. A wealth of historical/technical information collected over 10 years was extensively used to provide information for public interest. Author and poet Tim McNulty prepared the text. The Tribe's natural resources staff completed research/graphics/layout.

The inserts will be published (Sequim Gazette/Port Townsend Leader) on 9/13 and 9/20, 2000. Results/public reaction will be discussed following the publication.

Preparation of the insert was educational to staff in synthesizing complex technical information for public dissemination. An additional benefit was building upon the information base, and the relationship between the Tribe and local newspaper. Finally, the project emphasized the importance of conveying a sense of place for local residents in their home watershed, making regional natural resource issues more relevant.

Analysis of Atmospheric Source Contaminants in Biota of the North Shore Forested Watersheds of the Lower Mainland: A Pilot Study

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The impact of atmospheric metals and PAH contaminants on the watersheds of the Lower Mainland, British Columbia, was investigated using a biomonitoring approach. The moss *Isothecium stoloniferum* was sampled at nine forested locations and Perlidae and Pteronarcyidae stoneflies were sampled in 5 creeks on a west-east transect along the north side of the Lower Fraser Valley in March 2000. Selected metals and low molecular weight PAHs were significantly higher in moss samples from western sites. High molecular PAHs tended to be more concentrated in eastern areas. Stonefly data followed a similar but less significant trend. Moss samples from the Lower Fraser Valley were previously analyzed in 1993 for metals; these samples were collected in 1960-65, 1975-80, and 1993. Moss samples taken in March 2000 contained higher levels of manganese, chromium, nickel, zinc, and cadmium than in the previous investigations. Lead, in contrast, has further declined. Metals and selected PAH levels in the Fraser Valley were lower than in industrialized Europe but well above background. It is desirable to continue biomonitoring with a higher number of sites in the Lower Fraser Valley and possibly extend into the airshed south of the border to obtain a complete atmospheric deposition and impact pattern.

Small Streams Toxicity/Pesticide Study

Dean Wilson
King County Department of Natural Resources

Recent pesticide monitoring has shown the presence of a number of currently-used pesticides in small urban streams in King County, Washington. . A follow-up study was conducted in 1999 to assess toxicity and chemical concentrations of pesticides and metals in three of the small urban streams previously evaluated. Toxicity to the test species *Selenastrum capricornutum* was observed in the three test streams during three sampling events: spring and fall runoff and summer baseflow. Toxicity to *Ceriodaphnia dubia* was not observed at any time during the study. A total of 21 pesticides were detected out of 168 that were tested for, and 6 metals out of 13 that were tested for. Toxicity tests with each test species were conducted with both filtered and unfiltered samples. Toxicity to *S. capricornutum* observed in the unfiltered samples was significantly reduced in the unfiltered samples. Based on these data , it appears much of the observed toxicity was caused by exposure to particulate associated chemicals.

POSTER GROUP C: MARINE BIRDS AND MAMMALS

Pigeon Guillemot Breeding Colony Status for the Inland Marine Waters of Washington State, As Captured by PSAMP Efforts 1999-2000

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The pigeon guillemot, common throughout inland marine waters of Washington, is an ideal diving marine bird species for monitoring the health of Puget Sound's Nearshore waters during summer. Washington State Department of Fish and Wildlife and U. S. Fish and Wildlife Service conducted censuses of guillemot colonies May 1999 – 2000 and June Counts, limited to approximately the first three hours after sunrise of any given day, were made from boats at the 120 colonies listed in the Catalog of Washington Seabird Colonies (Speich and Wahl, 1989); the remaining marine inland waters were searched for colonies not listed in the colony catalog, providing complete coverage of the region. All colonies were counted regardless of colony size, with replicates on at least 2-3 different days. The average total count of breeding guillemots during both years was approximately 11,000. Over 260 colonies not previously recorded were documented, adding over 50 percent to the total number of guillemots known. The importance of counting smaller colonies was apparent; 78 percent of the colonies had <= 25 birds, comprising 20 percent of all birds counted. By continuing this survey that combines standardized timing, methodology, replicates, and geographic coverage within each season, pigeon guillemot population trends will be better understood.

Regional Sources of Toxic Chemicals in the Killer Whale (*Orcinus orca*) Food Chain: A Review

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Recently, high levels of contaminants, particularly PCBs, have been observed in southern resident Killer Whales (*Orcinus orca*). The risk of contaminant-related toxicity, coupled with declining prey abundance (salmon) and heavy vessel traffic, resulted in their recent listing as "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The origin of contaminants in areas frequented by resident killer whales, including Puget Sound and the Strait of Georgia, are largely unknown, since both regional and global sources contribute to contamination of these regions. In order to determine risk to killer whale health, we conducted a comprehensive review of existing information to identify the extent of regional contaminant sources. Although urban centers (e.g. Vancouver, Victoria, and Seattle) and certain industrial sources (e.g. pulp mills and mines), represent localized sources of pollutants, the Puget Sound basin represents a regional "hotspot". Consequent contamination of the marine food web likely contributes to contamination of the killer whale and may present a tangible risk to the health of this threatened species.

Common Murres in Puget Sound: Ecological Correlates And Conservation Implications

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In the state of Washington, Common Murres experienced a precipitous population decline in the early 1980's. The current population is one third of pre-1980 levels, and of 15 colonies listed in the Washington Seabird Catalog, breeding has only been recorded on Tatoosh Island. The cumulative effects of natural and anthropogenic factors, including increasing interactions between Bald Eagles and murres, oil spills and fishery bycatch, may be preventing population growth. This study describes the post breeding migration of Common Murres from Tatoosh Island. We conducted aerial radio-tracking surveys of 23 murres in 1999 and 2000, after birds had finished breeding, and the Puget Sound sockeye and chum gillnet fisheries had begun. The migration follows two major steps. After murres depart the colony, their initial movement is not random but rather is directed, heading east through the Strait of Juan de Fuca (SJF), into Northern Puget Sound. After reaching the eastern SJF, their directed movement ceases, and subsequent locations of individual murres become predictable in space. Murres may choose to spend the late summer in Northern Puget Sound because of the availability of predictable food resources and increased safety in calmer waters relative to the outer coast.

Salmon Farm-Pinniped Interactions in British Columbia: An Analysis of Predator Control, Its Justification and Alternative Approaches

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Predator control is widely practised in most forms of agriculture and aquaculture, including salmonid fish farming. Canada has a process whereby fish farmers can obtain authorisation to kill predators, particularly pinnipeds (seals and sea lions), but to date, this process, how it is being used by industry, and alternative measures to minimise the need for such killing have not been scientifically assessed. Here, we describe existing Fisheries and Oceans Canada (DFO) policy and hunting permit requirements associated with predator control; the impacts marine mammals are having on cultured fish production; the annual, seasonal and spatial pattern of kills; how this pattern is related to the abundance, distribution of haulouts and seasonal movements of pinnipeds; and the availability, effectiveness and use of alternate methodologies to deter pinniped impacts on fish farms. Establishment of Canada's Oceans Act in 1997 gave DFO the mandate for marine ecosystem management. With the recent growth in the coastal ecotourism industry and their interest in pinnipeds, there is now a need for this information. Pinnipeds are near the top of the marine food chain, and although they are not commercially exploited, their continued presence and occurrence in natural ecosystems at appropriate levels of abundance are important resource management considerations.

Status And Trends In Harbor Seals (*Phoca vitulina richardsi)* in Washington State: 1978-2000

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Aerial, boat and ground surveys have been conducted of coastal and inland waters of Washington state since 1978 to determine the distribution and abundance of regional harbor seal (*Phoca vitulina richardsi*) stocks. The coastal stock includes +150 haulout sites along the outer Washington coast from the Columbia River to Tatoosh Island; the inland stock includes +200 haulout sites in the Strait of Juan de Fuca, San Juan Islands, Puget Sound and Hood Canal. Aerial photographic surveys were the primary census method and followed standard protocols. Surveys were conducted during peak pupping periods for each stock: June 1-June 30 for the coastal stock, and August 1-September 1 for the inland stock. Counts were made of pups and non-pups hauled out during midday (0900 to 1500 hrs) low tides (+2.0 to -2.0 feet). Exponential and generalized logistic models were used to examine population trajectories and trends in abundance from 1978 to 2000. Washington's harbor seal populations are considered abundant and healthy, numbering in excess of 34,000 seals (coastal stock +18,000 seals; inland stock +16,000 seals). Population growth analysis indicate annual growth rates of 6-8 percent over the last 20 years for Washington's harbor seal populations. Population growth of the coastal stock appears to have stabilized and is considered at or near carrying capacity; population growth of the inland stock numbers has slowed and appears to be approaching carrying capacity.

Changes in Sea Otter Benthic Prey and Algal Communities of the Olympic Coast National Marine Sanctuary During 12 Years of Rapid Sea Otter Range Expansion

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This report summarizes the changes in the distribution and abundance of selected benthic species within sea otter prey communities along the Washington State Olympic coast between 1987 and 1999. During this 12 year period, the Washington State otter population has undergone a dramatic increase in both numbers and range, now occupying habitats that were otter free in when first sampled in 1987. Quantitative video and *in situ* counts of invertebrate prey and algal cover at permanent monitoring sites established along the coast reveal significant changes occurring as sea otters expanded their range into previously unexploited habitats. Invertebrate prey such as sea urchins that were abundant just outside the boundaries of the 1987 sea otter range, are now virtually absent in these formerly productive commercial harvest areas. Understory foliose red and coralline algae, along with the kelps have also undergone changes in abundance as otters removed large invertebrate grazers from the newly occupied communities.

Carrying Capacity Estimates for the Washington State Sea Otter (*Enhydra lutris kenyoni*) Population

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Carrying capacity (K) estimates for the Washington sea otter (*Enhydra lutris kenyoni*) population were obtained as products of the density of sea otters at equilibrium within a portion of their existing range and the total amount of available habitat. Sea otter habitat was classified during aerial surveys along the Washington coast in March 2000. Substrate type and kelp composition were characterized from the coast to the 40 m depth contour and sea otter habitat was classified as rocky, sandy, or mixed. Maximum foraging depths and maximum distance from shore were calculated for each of 68 sea otters radio-tagged between 1995 and 1999, and were used to approximate the offshore extent of sea otter habitat. The Geographic Information System software packages ARC/INFO® and ArcView® were used to calculate the area (km^2) and coastline (km) available to sea otters within each habitat type, and the offshore habitat use by sea otters. The most current population survey data (1996-1999) were used to obtain equilibrium densities of sea otters in rocky habitat in Washington. Because sea otters have only recently occupied sandy or mixed sites, the equilibrium densities for these habitat types represent a proportional density based on current counts in the rocky equilibrium region in Washington and available data from the California sea otter population. The Washington sea otter population is small and still growing, and population status relative to equilibrium density is uncertain. Consequently, the estimates of K are subject to change as more information becomes available.

Evidence Of *Brucella sp.* Infection in Pacific Harbor Seals (*Phoca vitulina richardsii*) and California Sea Lions (*Zalophus californianus*) from Washington

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Blood samples were collected from harbor seals and California sea lions during capture operations in Washington, from 1994 to 1999. Positive or suspect titres to *Brucella abortus* antigen occurred in 81 of 713 harbor seals (11 percent) and ten of 156 California seal lions (6 percent) captured. Since 1995, blood samples and tissues were also collected from stranded marine mammals and tested for *Brucella. Brucella sp.* was cultured and isolated from seven harbor seals from Puget Sound. *Brucella* sp. has been isolated from all lymph nodes and most body tissue and fluids (14 of 19). *Brucella* sp. isolates from Washington seals appear to be biochemically similar although genetically distinct to a strain isolated from a seal in the United Kingdom. Most affected seals were emaciated and had severe verminous pneumonia with intralesional *Parafilaroides sp.* lungworms. Some adult worms had large numbers of minute bacterial coccobacillus along the inner membrane of the uterus and within gut lumen. Immuno-histochemistry revealed large quantities of an antigen within *Parafilaroides sp.*, within cytoplasm of leukocytes in surrounding pulmonary parenchyma and affect lymph nodes. WDFW has begun screening marine mammals for evidence of *Brucella.* Harbor porpoise (five of 16) and northern fur seals (two of 5) had suspect or positive titres to *Brucella* antigen. Little is known of this new marine *Brucella* species. Though recent studies indicate that domestic livestock maybe infected by this strain.

Diet Of Harbor Seals in Hood Canal During 1998 and 1999

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Fecal samples (scats) were collected in 1998 and 1999 from harbor seal haulout sites at Quilcene Bay, Dosewallips River, Duckabush River, Hamma Hamma River and Skokomish River in Hood Canal to investigate harbor seal diet. Samples were collected during fall 1998 and 1999 and spring 1999. Scats were rinsed in nested sieves and all hard parts were removed. All prey parts (otoliths, skeletal structures, cartilaginous parts and cephalopod beaks) recovered from scats were identified to the lowest possible taxon and then sided and enumerated to determine minimum number of individuals for each species. Harbor seal diet was described by frequency of occurrence (FOC). More than 20 prey species were identified from over 1100 scats, with Pacific hake, Pacific herring and salmon being the most important prey (>20 percent FOC) of harbor seals. Other important prey included Shiner perch, Market squid, Pacific staghorn sculpin, Northern anchovy and Plainfin midshipman. Using all diagnostic structures (bones and otoliths) versus only otoliths to characterize diet varies in its importance based on the prey species consumed. Using all structures was particularly important for identification of adult salmon that have small and fragile otoliths.

Foraging Ecology of Harbor Seals in Hood Canal and the Potential Impacts on Threatened Summer Chum Stocks

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In the fall of 1998-2000, the Washington State Department of Fish and Wildlife (WDFW) and Washington Cooperative Fish and Wildlife Research Unit began efforts to evaluate the potentially negative effects of predation by pinnipeds on the recovery of summer chum salmon runs in Hood Canal. Hood Canal has been the focus of these efforts because of the isolated nature of the system and the presence of abundant harbor seal (*Phoca vitulina*) populations along declining summer chum stocks. Surface observations were used to document harbor seal predation on returning adult salmon off the mouths of the Quilcene, Dosewallips, Duckabush, and Hamma Hamma river systems. Seals were observed consuming summer chum, coho, and fall chum in all three years. Additionally, steelhead, pink and chinook salmon were observed in 1999. During 1998 and 1999, 1017 (98: 601; 99:416) scat samples were collected at five haul-outs to determine food habits and provide additional insights into salmonid consumption. Key questions regarding nighttime predation rates and allocation of 'unidentified salmonid' predations to a particular species remain unanswered. Preliminary results suggest that harbor seals have the potential to negatively impact recovery of summer chum runs in those river systems with small escapements and habitat accessible to seals.

Status and Trends for A Suite of Key Diving Marine Bird Species Characteristic of Greater Puget Sound, As Examined by the Marine Bird Component, Puget Sound Ambient Monitoring Program (PSAMP)

David R. Nysewander, Joseph R. Evenson, Bryan L. Murphie, and Thomas A. Cyra
Washington State Department of Fish and Wildlife

Monitoring efforts were designed to focus on species that might serve as indicators of environmental change and health of Greater Puget Sound. A set of species were selected using criteria related to dependence upon marine waters of Puget Sound, peaks of abundance during certain survey windows, use of different representative key marine habitats, and other concerns due to limited numbers or special vulnerability to human caused mortality.

Aerial surveys of marine birds were conducted annually 1992-2000 during each winter and most summer survey windows, sampling nearly every portion of the inner marine waters of Washington State. Surveys were stratified by two depth strata: nearshore (< 20 m) and offshore (> 20 m). These surveys annually covered approximately 15 percent to 19 percent of the nearshore and 4 percent to 6 percent of the offshore strata.

Trends in changing densities or numbers over the last 10-20 years are examined for nine key species groups: scoters, scaups, goldeneyes, bufflehead, harlequin duck, loons, western grebe, rhinoceros auklet, and pigeon guillemot. The results includes a mixture of changes that range from large decreases (grebes and some sea/bay duck species) to stable or slowly decreasing patterns (auklets, guillemots, remaining diving ducks), with a few suggestions of increases (loons).

Summer and Winter Distribution and Abundance of Seabirds in Washington, 1996-2000

C.W. Thompson
Washington State Department of Fish and Wildlife
G. Ford
R.G. Ford Consulting, Inc.
K. Ostrom
U.S. Fish and Wildlife Service

In order to collect baseline data on the distribution and abundance of seabirds along the Strait of Juan de Fuca and outer coast of Washington, including the Columbia River estuary, Willapa Bay, and Grays Harbor, Washington State Department of Fish and Wildlife (WDFW) conducted extensive at-sea surveys for seabirds, primarily within five km of shore, in the summers of 1996-2000, and winters of 1996-1998. These data were collected by methods that accurately measure observer effort as well as transect location. Therefore, bird densities can be standardized by effort and validly compared between treatment groups (e.g. location, year, season, month, bird species, water depth, distance from shore). Patterns of distribution and abundance of many species, and causes for these patterns (e.g. habitat correlates) will be presented. Summer and winter bird densities of species of concern (e.g., Marbled Murrelets and Common Murres) vary tremendously both spatially and temporally highlighting the fact that (1) population trends of seabird species are inherently difficult to accurately monitor, and (2) optimal sampling designs for monitoring different seabird species must reflect their respective differences spatial and temporal distribution and abundance.

POSTER GROUP D: TOXIC CONTAMINANTS

Cytochrome P450 1A Enzymes As Non-Invasive Biomarkers of Contaminant Exposure in Skin from Harbour Seals *(Phoca vitulina)*

Marta Assunção and Peter Ross
Institute of Ocean Sciences,
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The marine environment is contaminated with persistent chemicals including PCBs (polychlorinated biphenyls), PCDDs (polychlorinated-dibenzo-p-dioxins) and PCDF (polychlorinated-dibenzo-p-furans). These lipophilic compounds tend to biomagnify in the food chain reaching high levels in marine mammals, including harbour seals. The cytochrome P450 1A subfamily has been used as biomarker of contaminant exposure as a result of their induction in wildlife (fish, birds, mammals) that inhabit industrialized areas. By determining the CYP 1A1/2 content (western blotting) and its associated enzyme activities (EROD and MROD), we are developing a minimal-invasive method by using this biomarker in skin biopsy samples collected from free-ranging harbour seals. Skin/blubber biopsies were collected from 20 young seals, aged approximately 4 to 6 weeks, from the Fraser estuary near Vancouver, British Columbia. Two induction studies using b-naphthoflavone (BNF), a non-toxic inducer of CYP1A enzymes, were also carried out in two groups of six seals each as a means of characterizing the responsiveness of these enzymes using both in vivo oral (50 mg/kg body weight) and topical (0.12mg BNF/cm2) administration. This non-destructive biomarker approach may provide us with an important tool for understanding the risks associated with contaminant exposure in different marine mammals, including those from which no liver samples can be obtained (e.g. killer whales).

An Ecosystem Approach to Assessing the Accumulation of Persistent Organic Pollutants (POPs) In The Food Chain of Harbour Seals *(Phoca vitulina)* Inhabiting the Coastal Waters of British Columbia And Washington

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Steve Jeffries
Washington State Department of Fish and Wildlife
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There is increasing concern for the ecological and human health risks of persistent organic pollutants (POPs). These contaminants have been found in higher trophic level organisms including marine mammals. Exposure to POPs has been associated with adverse health effects in marine mammals including immunotoxicity and endocrine disruption. Recent research has found high PCB concentrations as well as a contaminant-related disruption of retinoid physiology in B.C. and Washington harbour seals (*Phoca vitulina*). Tools and techniques including congener-specific contaminant analyses, fatty acid signature analyses, stable isotope ratios, and multivariate

statistical analyses will enable us to characterize the bioaccumulation of POPs in the harbour seal food chain (eg. herring, hake, salmonids). Understanding the origin of these POPs in harbour seals is hampered by the complexity of transport and fate processes, which reflect a combination of both local and global (eg. atmospheric deposition) sources. We are developing a contaminant-based model to describe bioaccumulation in the food chain of harbour seals inhabiting Puget Sound and the Strait of Georgia. This research will help to elucidate pathways of POPs in Puget Sound and the Strait of Georgia using harbour seals as sentinels of marine ecosystem contamination.

A Multivariate Statistical Approach to Characterizing Impacts from Combined Sewer Overflows Using Regional Chemistry Data

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To satisfy requirements in the City of Seattle's NPDES permit, a CSO characterization project was designed to predict the chemical and bacteriological quality, and ultimately the potential impact on receiving water quality, of Seattle's CSO discharges using data from CSOs in other Northwest municipalities. Statistical evaluations were performed to identify relationships between the chemical concentrations in CSOs in these municipalities and explanatory variables such as land use, the percentage of sewage in the CSO effluent, and the number of rainstorm-free days prior to the CSO discharge. Land use was the most important explanatory variable for chemical concentrations. Of the five chemicals of concern examined quantitatively (copper, zinc, bis(2-ethylhexyl)phthalate, phenanthrene, and fluoranthene), only copper had a reasonable potential to exceed ambient WQC at the end of the pipe.

Should We Be Concerned About Estrogenic Compounds in Puget Sound Waterways? Adult Male English Sole Collected Near Urban Areas May Provide the Answer

Daniel P. Lomax, Lyndal L. Johnson and William T. Roubal
National Oceanic and Atmospheric Administration
James E. West and Sandra M. O'Neill
Washington State Department of Fish and Wildlife

Vitellogenin (Vtg) is a yolk protein produced in the liver of oviparous animals in response to estrogen. Its synthesis is normally observed only in sexually mature females with developing eggs, however male animals can synthesize Vtg when exposed to exogenous estradiol or to substances that mimic estrogens. Thus, the abnormal production of Vtg in male animals can be used as a biological indicator for exposure to environmental estrogens. As part of the Puget Sound Ambient Monitoring Project (PSAMP), we collected plasma from adult male English sole from numerous urban embayments in Puget Sound between 1997-99. Among the sites sampled are areas with elevated levels of compounds in bottom sediments with suspected estrogenic activity, such as certain phthalates, DDTs, and PCB congeners (Sinclair Inlet, Duwamish Waterway, Elliott Bay). Male English sole plasma from these sites and several clean reference sites are being analyzed utilizing a validated enzyme-linked immunoassay (ELISA) for plasmatic Vtg in English sole. The presence or absence of Vtg in these samples will help to answer the above question. The results of this study will be presented and the implications discussed.

The Liver Cytochrome P450 Enzyme System: A Biomarker of Contaminant Exposure in English Sole and Harbour Seals In Southern British Columbia

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Richard F. Addison and Peter S. Ross
Institute of Ocean Sciences

We are assessing the use of the liver enzyme cytochrome P450 1A (CYP1A) as a biomarker for contaminant exposure in fish and marine mammals in southern British Columbia. Hepatic ethoxyresorufin (EROD) activity and CYP1A levels were measured in English sole caught at five sites in and around Vancouver Harbour. We found that fish with high EROD activity and CYP1A levels came from sites containing relatively high sediment levels of polyaromatic hydrocarbons and organochlorines. There also appeared to be positive correlations between EROD and CYP1A results, liver lesions, and bile levels of low molecular weight aromatic hydorcarbons. In a separate study, we collected liver biopsies from 16 young harbour seals. Seals were live-captured from the Fraser River estuary near Vancouver, British Columbia and temporarily housed in captivity. Liver biopsies were conducted under general anaesthetic. We will measure EROD activity and CYP1A1/1A2 levels in these liver samples, and these results will be compared to enzyme levels detected in other physiological compartments, as well as to other toxicological endpoints. This work will further the position of the harbour seal as an important sentinel of marine ecosystems in British Columbia.

Vitamin A as a Biomarker of Contaminant Toxicity in Harbour Seals

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Fisheries and Oceans Canada

Vitamin A is a collective name for a group of small fat-soluble molecules (also called retinoids) that are essential to all mammals in processes of growth and development, as well as for the maintenance of reproductive, endocrine and immune systems. Although its levels are highly regulated within the body, environmental contaminants, such as polychlorinated and -brominated compounds (e.g. PCBs), can disrupt the homeostasis of this dietary hormone. Vitamin A therefore serves as a biomarker of contaminant exposure and effect. Recently, our laboratory documented a contaminant-related increase in circulatory vitamin A in free-ranging harbour seals sampled in British Columbia and Washington. As part of our ongoing ecotoxicology research, we live-captured and temporarily housed 20 healthy, recently weaned harbour seal (*Phoca vitulina*) pups from British Columbia's coast. Blood and micro-scale tissue samples (skin, blubber and liver biopsies) obtained during this semi-field study were quantified for different retinoids. This compartment model of vitamin A homeostasis in harbour seals will i) document mechanisms of action which would explain the observed vitamin A disruption in seals; and ii) serve to validate novel means to assess contaminant-related toxicity in species where blood sampling is not possible (e.g. killer whales).

Temporal Trends in Toxicopathic Hepatic Lesion Occurrence in English Sole (*Pleuronectes vetulus*) from Puget Sound, Washington: Results of the Puget Sound Ambient Monitoring Program; 1989-1999

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James West
Washington State Department of Fish and Wildlife
Beth Horness
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The Washington State Department of Fish and, as part of the Puget Sound Ambient Monitoring Program has monitored the occurrence of toxicopathic liver lesions and contaminant levels in muscle and liver tissue in English sole *(Pleuronectes vetulus)* at more than 40 sites in Puget Sound. Lesion prevalence in English sole is monitored as a general indicator of contaminant-related fish health because research by the National Marine Fisheries Service and Fish and Wildlife has shown that although the risk of developing liver lesions increases with fish age, exposure to contaminated sediments particularly high molecular weight PAHs, is the main risk factor associated with developing lesions. Furthermore, reproductive impairment has also been observed in English sole at sampling sites with elevated occurrences of liver lesions.

Six sites were monitored annually between 1989 and 1999 to track temporal changes in lesion occurrence and included two non-urban (Strait of Georgia and Hood Canal), one near-urban (Port Gardner) and three urban locations (Elliott Bay, Sinclair Inlet and Commencement Bay). Average lesion occurrence in English sole was highest at Elliott Bay and Commencement, intermediate at Sinclair Inlet and Port Gardner and lowest at Strait of Georgia and Hood Canal. As compared to the risk of liver lesion occurrence at 19 other non-urban, relatively uncontaminated reference sites (defined as 1.0), the risk of developing liver lesions apparently increased at Elliott Bay between 1989 and 1999 but not at other sites. Possible factors affecting the increase in liver disease in English sole from Elliott Bay are presented.

The Application of the SEDCAM Sediment Attenuation Model to Nonpolar Organic Compounds

Bruce W. Rummel
Taylor Associates

The SEDCAM sediment attenuation model incorporates three processes occurring in the mixed sediment layer--accumulation, burial, and loss from diffusion or degradation. It has been used in program guidance for the Washington Sediment Management Standards to evaluate natural recovery at hazardous waste sites and has been applied to Puget Sound sediments for evaluating source control methods. The model has been typically applied to sediments in Puget Sound using bulk (dry-weight normalized) sediment concentrations of substances. The model can be used for nonionic, nonpolar organic compounds by adjusting for carbon-normalized concentrations. The adjustment consists of dividing the term expressing the rate of mass accumulation (M) by the concentration of total organic carbon concentration in the depositing particles and dividing the term expressing the total accumulation of mixed sediment (S) by the total organic carbon concentration in the mixed sediment layer.

POSTER GROUP E: CONTAMINATED SEDIMENTS

Using GIS to Evaluate Sediment Contamination Impacting Duwamish Estuary Habitats

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The degree to which environmental contamination impacts natural resources is a function of many variables. In addition to the concentration and toxicity of a contaminant in the environment, several other factors affect organism exposure and uptake. An examination of the distribution of habitat types in a study area can provide information pertinent to the analysis of the effects of contaminants on ecological receptors of concern to resource managers.

In areas where several habitat types occur over a relatively small area, and many different hazardous substances have been released and are distributed in a heterogeneous fashion, the analysis of the absolute and relative impacts of these substances is complex. A GIS project has been developed to aid in the analysis of impacts to natural resources in the Duwamish River from past and current releases of hazardous substances. A base map was created from aerial photography taken during a low tide event in July of 1999. Habitats were delineated using functional categories developed collectively by the Elliott Bay & Duwamish Natural Resource Trustees in 2000. A database was created to compile sediment chemistry results from over 1,000 sampling stations from more than a dozen sampling events undertaken by various parties over the last decade.

The GIS project and associated database allow the user to analyze the distribution of one or several contaminants, relative to different habitat types of varying productivity and resource utilization.

Sediment Flux Assessment in Sinclair and Dyes Inlet

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Joel Guerero and Jon G. Groves
Computer Sciences Corp.
Eric Crecelius
Battelle Marine Science Lab

Sediments are a potential repository for contaminants, and subsequent remobilization of these contaminants can contribute to the overall budget and determination of Total Maximum Daily Loadings (TMDLs). Flux of metals contamination as well as conventional water quality analytes were measured at 7 stations within Sinclair Inlet and 2 stations in Dyes inlet using the Navy's Benthic Flux Sampling Device (BFSD) during the spring of 2000. Sites were selected to represent a range of bulk contaminant loadings and geochemical conditions as determined from a number of historical studies. Conventional water quality analytes include nitrate, nitrite ammonia and phosphate to assess nutrient loading. Oxygen demand was also measured. Metal contaminants measured include antimony, arsenic, cadmium, chromium, copper, lead, manganese, nickel, silver and zinc and were selected based on previous listing on the 303d list and other indications of ecological risk. Flux was measured at each site for 72 hours. Results are presented in poster format. This study was conducted in support of the Puget Sound Naval Shipyard ENVVEST project

Survey of Sediment Quality in Puget Sound, 1997-1999—The "Sediment Quality Triad" Synthesis

M. Dutch, S. Aasen, K. Welch and C. Ricci
Washington State Department of Ecology
E.R. Long
National Oceanic and Atmospheric Administration

Surficial sediments from 300 locations throughout Puget Sound were collected during June of 1997, 1998, and 1999, and tested to determine measurements for the "Sediment Quality Triad" (Long and Chapman, 1985) parameters of toxicity, chemical contamination, and benthic infaunal community structure. This effort was part of a three-year cooperative agreement between the Sediment Monitoring Component of the Puget Sound Ambient Monitoring Program (conducted by the Washington State Department of Ecology) and the National Oceanic and Atmospheric Administration's National Status and Trends Program. The results from four toxicity tests, concentrations of over 160 chemical compounds measured in the sediments, and a suite of benthic infaunal indices, including total abundance, major taxa abundance, taxa richness, Pielou's evenness, Swartz's dominance, and the top ten dominant species, were compared both within and among the 300 Puget Sound stations. Suites of stations are identified and displayed which provide evidence either for or against "pollution-induced degradation" (Chapman, 1996) of the sediments. Spatial patterns of "pollution-induced degradation" are noted. The spatial extent of "pollution-induced degradation", i.e., the total number of stations, total area (km^2), and percent of the total study area that each of these stations suites represents, is summarized for the Puget Sound study area.

Survey of Sediment Quality in Puget Sound, 1997-1999—Chemical Contamination

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E.R. Long
National Oceanic and Atmospheric Administration

Surficial sediments from 300 locations throughout Puget Sound were collected during June of 1997, 1998, and 1999, and tested to determine the extent of chemical contamination for over 160 metal and organic compounds. This work was conducted as part of a three-year cooperative agreement between the Sediment Monitoring Component of the Puget Sound Ambient Monitoring Program (conducted by the Washington State Department of Ecology) and the National Oceanic and Atmospheric Administration's National Status and Trends Program. Spatial patterns and gradients of chemical contamination, along with estimates of the spatial extent of chemical contamination throughout the study area, are displayed. As would be expected, the spatial patterns indicate the greatest degree of chemical contamination in and around urban/industrialized embayments, including Everett Harbor, Elliott Bay, Port Washington Narrows, Sinclair Inlet, Commencement Bay, and Budd Inlet. Spatial extent calculations (i.e., percent of the 2363.3 km^2 study area in which chemical concentrations exceed state and national guidelines), were determined for the 54 compounds for which chemical guidelines exist. The spatial extent of chemical contamination was less than 1 percent of the total study area for all but a few compounds. There were a total of 137 stations where contaminant levels exceeded state and/or national guidelines for at least one compound, representing 804.8km^2, or 34.5 percent of the total study area (2363.3 km^2).

Survey of Sediment Quality in Puget Sound, 1997-1999—Toxicity

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E.R. Long
National Oceanic and Atmospheric Administration

Surficial sediments from 300 locations throughout Puget Sound were collected during June of 1997, 1998, and 1999, and tested to determine toxic conditions as part of a three-year cooperative agreement between the Sediment Monitoring Component of the Puget Sound Ambient Monitoring Program (conducted by the Washington State Department of Ecology) and the National Oceanic and Atmospheric Administration's National Status and Trends Program. Spatial patterns and gradients of toxicity, along with estimates of the spatial extent (km^2) of toxicity throughout the study area, are displayed for the results of four toxicity tests (i.e., 10-day amphipod survival (*Ampelisca abdita*) (solid phase), sea urchin fertilization (*Strongelocentrotus purpuratus*) (pore water), microbial bioluminescence (Microtox™) (organic solvent extract), and cytochrome P450 HRGS (organic solvent extract).

An Analysis in Support of Sediment Quality Thresholds For Polycyclic Aromatic Hydrocarbons (PAHs) To Protect Estuarine Fish

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Under the U.S. Endangered Species Act and the Essential Fish Habitat provisions of the Sustainable Fisheries Act, it is the responsibility of the National Marine Fisheries Service (NMFS) to safeguard the health of fish in estuarine and coastal waters. This includes assessment of the impacts of exposure to toxic chemicals on fish and their critical habitat. This analysis was conducted to assist resource managers in the NMFS in determining when fish are exposed to potentially harmful concentrations of one of the most common environmental contaminants, polycyclic aromatic hydrocarbons (PAHs). Effects thresholds were estimated primarily through segmented regression of site-specific sediment PAH concentrations and associated disease prevalences in a resident fish species, English sole. The analyses and supporting data encompasses several endpoints, including DNA damage, liver lesions, and impacts on growth and reproduction. In general, liver lesion prevalences, DNA adduct levels, and impacts on growth and reproduction were minimal at sediment PAH concentrations at or below 1000 ppb. Above 1000 ppb, there appears to be a substantial increase in the risk of contaminant-related injury to English sole.

Sediment Quality Evaluation in an Urban Lake—Lake Sammamish, Washington

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King County Department of Natural Resources

King County recently completed a sediment quality evaluation of Lake Sammamish. Lake Sammamish is a relatively large lake located approximately 16 km east of Seattle in one of the fastest growing areas of Washington State. The lake is approximately 13 km long and 2 km wide with a surface area of 19.8 km^2. The lake is monomictic and the hypolimnion experiences anaerobic conditions much of the summer. The primary objectives of the study were: (1) to conduct a baseline sediment quality evaluation including both chemical and biological testing; (2) to evaluate relative distribution of potential contaminants of concern; (3) to evaluate sediment

toxicity; and (4) evaluate benthic community structure and compare these data with sediment toxicity results. Sediments collected from 16 stations were analyzed for base/neutral/acid extractable organic compounds, pesticides and herbicides, polychlorinated biphenyls, metals, tributyltins, total petroleum hydrocarbons, other conventional parameters. Chemical data were compared to the Washington State draft freshwater sediment guidelines. Three toxicity tests were conducted; *Hyalella azteca* (survival), *Chironomus tentans* (growth and survival), and Microtox®. Benthic invertebrate samples were collected and organisms were identified to species when possible. The highest levels of sediment associated contaminants were found in the vicinity of stormwater discharges. A number of metals and organic compounds were found to exceed the sediment guidelines, however, toxicity test results did not indicate these sediments were having a significant adverse impact on the benthic community. Because the lake is also organically enriched due to relatively high phosphorus loading, it is difficult to determine to what extent the benthic community structure is adversely impacted by sediment associated chemicals.

Biomarker and Histopathologic Responses in Flatfish Following Site Remediation in Eagle Harbor, Washington

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National Oceanic and Atmospheric Administration

Eagle Harbor in Puget Sound became a Superfund site in 1987 due to high sediment concentrations of polycyclic aromatic hydrocarbons (PAHs) released chronically from a nearby creosoting facility. Earlier studies with English sole from this site (1984-86) demonstrated high prevalences of toxicopathic liver lesions, including neoplasms, in resident sole. Inducibility of neoplasia-related lesions by injections of a PAH-rich fraction extracted from Eagle Harbor sediment has also been shown. Further studies (1986-88) also sampled resident starry flounder and rock sole, and incorporated biomarkers of PAH exposure and effect, including hepatic CYP1A expression, biliary fluorescent aromatic compounds (FACs), and hydrophobic DNA adducts in liver. Hepatic lesion prevalences and biomarker values in these species from Eagle Harbor were among the highest found in Puget Sound. In a combined effort by the USEPA and US Army Corps of Engineers, a cap of relatively clean sediment was placed (9/93-3/94) over the most contaminated portions of Eagle Harbor as an attempt to sequester PAH-contaminated sediments. Lesion prevalences and biomarker values just before capping began were generally reduced compared to historical data, consistent with creosoting facility closure and site-based source controls. Data from fish collected immediately after and at regular intervals up to 72 months after cap completion show an overall decreasing trend in prevalences of certain hepatic lesions and response levels for biomarkers of PAH exposure and effect, strongly suggesting that the sediment capping process has been relatively effective in ameliorating PAH exposure and associated effects in resident flatfish species.

POSTER GROUP F: MARINE WATERS

Assessing Sensitivity to Eutrophication of the Southern Puget Sound Basin: Spatial and Seasonal Perspectives

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Washington State Department of Ecology

The southern basin of Puget Sound (south of the Tacoma Narrows) is characterized by slow circulation and shallow bathymetry, relative to other major Puget Sound basins. Human population growth in the adjoining watershed areas is projected to grow steadily, bringing increasing development, deforestation, and shoreline impacts. Washington State Department of Ecology/Puget Sound Ambient Monitoring Program Marine Waters Monitoring data show that a high percentage of monitoring stations in South Puget Sound exhibit characteristics indicating sensitivity to eutrophication. Despite relevancy to planning, there is very little information about the nutrient, oxygen, and phytoplankton dynamics in South Puget Sound. We are currently involved in two studies addressing this issue: 1) SPASM, Southern Puget Sound Area Synthesis Model, utilizing computer models of hydrodynamics and water quality, and 2) CISNet, Coastal Intensive Site Network, developing an in-situ profiling mooring (ORCA, Ocean Remote Chemical Analyzer). In support of both of these studies, we conducted a series of intensive cruises during 1997-2000 to measure basic water properties such as nutrient, dissolved oxygen, and chlorophyll levels at 80 stations within South Sound. We present spatial and seasonal patterns of variation in these properties with identification of the areas potentially sensitive to eutrophication. Sections displaying contoured values of salinity, temperature, nutrient, dissolved oxygen, and chlorophyll levels show areas, such as Budd, Carr and Case Inlets, where stratification persists and where low dissolved oxygen concentrations develop. In addition to these observations, we tested whether primary

production was nutrient-limited at five of these stations each cruise. While all stations show some degree of nutrient-sensitivity, this condition was especially pronounced in Carr Inlet. The data collected from these cruises show that concerns about water quality impacts from growth-related eutrophication in South Sound are well-founded and should be taken into consideration in planning.

Dairy Waste Impacts on Tribal Shellfish: The Cow-to-Clam Connection

Michael Cochrane
Northwest Indian College

This presentation will present results of fecal coliform monitoring of the Nooksack River watershed in Whatcom County Washington over the last three years. Also described will be the development of a watershed wide monitoring plan, point and nonpoint source identification, and fecal coliform transportation dynamics.

The problem is chronic and mostly a problem of adjacent regulatory standards. It takes a fecal coliform count of over 200 to violate Class A water quality standards at the mouth of the Nooksack River. It only takes a fecal coliform count of 44 to violate Shellfish growing water standards three miles downstream.

The current fecal coliform standard was designed to be an indicator of human health risk from human viruses coming from human sewage. Cows don't get human viruses. So, in this case, we have an indicator of human health risk being applied to a non-human source.

This presentation will be of special interest to those curious about the role a Federally recognized Treaty Tribe can play in focusing attention and resources on water quality issues.

Spatial and Temporal Patterns of Paralytic Shellfish Poisoning Toxin in Puget Sound

Tim Determan
Washington State Department of Health

The Washington State Department of Health (DOH) monitors levels of paralytic shellfish poisoning toxin (PSPT) in mussels taken every two weeks from sentinal sites located throughout Washington State marine waters. Results from thirty sites in Puget Sound are examined annually to determine spatial patterns and temporal trends as part of the Puget Sound Ambient Monitoring Program (PSAMP). Results of the analysis through December 1999 will be presented.

Oceanographic Survey of Commencement Bay, Washington—Spring 2000

Dan Huisjen, Andrea Brannon, Hwa Kim and Cheryl Greengrove, Ph.D.
University of Washington

Oceanographic measurements of Commencement Bay, Washington, made in the spring of 2000 will be presented. CTD/Rossette casts were made to near bottom depths across the mouth of the bay, across the Tacoma tide flats waterway entrances, and at points leading into Colvos Passage and the Tacoma Narrows. Vertical plankton tows to 30 m were also collected at select stations. Our investigations focused on current, plankton, nutrient, temperature and salinity data, which are displayed and compared with historical data. In addition, historic current data within the bay are displayed in animated format by converting data points from a multi-depth 1980 drogue study into animated form, using modern GIS software unavailable at the time of the original study.

Seasonal Cycle of Deep Water Properties in Puget Sound, Their Interannual Variability, and Sensitivity to Climatic Factors

Mitsuhiro Kawase
University of Washington

Historical and contemporary deep hydrographic measurements in the Main Basin of Puget Sound are analyzed in order to characterize the canonical seasonal cycle of deep water properties and their interannual variability. A well-defined seasonal cycle is found. Temperature peaks in late August to early September with an average maximum value of 12.5 C and bottoms in February with an average minimum of 8 C. Salinity maximum is typically reached in October with an average value of 30.7 PSU, and the minimum between February and May with an average of 29.5 PSU. Salinity shows significant year-to-year variability. The minimum value of salinity, for example, varies by as much as 0.7 PSU, which is 60 percent of the average range of the seasonal cycle, and the timing of the minimum also varies, in some years occurring as late as in June. In contrast, the maximum salinity remains remarkably stable from year to year, except it may fall below 30 PSU in years in which coastal upwelling in the Pacific coast is reduced due to the influence of El Nino - Southern Oscillation. Correlation of deep water properties with other major climatic parameters, and sensitivity of Puget Sound circulation to changes in forcing, will be discussed.

Spatial and Temporal Variations of Conventional Water Quality Parameters in Marine Waters of the Central Puget Sound Basin

Scott Mickelson
King County Department of Natural Resources

Population growth in King County has necessitated planning a new wastewater treatment plant with a Puget Sound outfall. King County is conducting a marine outfall siting study (MOSS) as part of the planning process. A study of conventional water quality parameters in central Puget Sound was undertaken to characterize spatial and temporal variations of these parameters.

The two-year study began in December 1998 with CTD transects at seven locations in the central Puget Sound Basin and Possession Sound. Marine water samples have also been collected monthly from twelve sites since February 1999. Water quality parameters have been measured using a combination of *in situ* sensors and laboratory analyses and include nutrients, chlorophyll, dissolved oxygen, salinity, temperature, turbidity, solids, density, and optical properties.

Preliminary analysis of the data indicates classic patterns of temporal variation in conventional water quality parameters due to seasonal nutrient uptake and primary production. The data also indicate spatial variation between sampling locations such as a seasonal depression of dissolved oxygen in Possession Sound. Results from this study will be combined with other MOSS studies to assist the outfall siting and design process and allow evaluation of potential impacts to the marine environment from secondary treated wastewater.

Characterization of Trace Metal Concentrations in Marine Waters of the Central Puget Sound Basin

Scott Mickelson, Melinda Brockington, Scott Carpenter and Thomas Georgianna
King County Department of Natural Resources

Population growth in King County has necessitated planning a new wastewater treatment plant in northern King County or southern Snohomish County with a Puget Sound outfall. King County is conducting the marine outfall siting study (MOSS) to assist in the outfall siting and design process. A study of trace metal concentrations in central Puget Sound marine waters was undertaken as part of MOSS. This study characterizes existing conditions in Puget Sound and allows evaluation of potential impacts to the marine environment from secondary treated wastewater.

Marine water samples were collected monthly from April 1999 to May 2000 from three depths at eight sampling sites in Puget Sound. Sampling followed "clean hands/dirty hands" protocols and employed new, non-contaminating sampling gear. Samples were analyzed for 14 trace metals using analytical technologies that provided ultra-low level detection limits. Sample preparation employed a reductive co-precipitation technique to remove matrix interference and pre-concentrate the sample.

Preliminary statistical analysis of the data indicates that sampling has been sufficient to characterize the mean for each metal at every site and depth sampled. The data are symmetrically distributed and display small coefficients of variation which enables the use of a one-way ANOVA for testing differences among sites.

A Three-dimensional Water Quality Model Of Southern Puget Sound

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A three-dimensional hydrodynamic and water quality model of southern Puget Sound was developed based on the EFDC model[1]. The water quality model simulates the concentration of dissolved oxygen (DO) in response to primary production of phytoplankton, oxidation of organic material, and sediment flux. Of the 21 possible state variables in EFDC, the model of southern Puget Sound includes: two phytoplankton groups, three forms of organic carbon, three forms of organic phosphorus and nitrogen, dissolved reactive phosphorus, ammonia nitrogen, nitrate plus nitrite nitrogen, chemical oxygen demand, and dissolved oxygen. Fecal coliform was also included.
A sediment process model is coupled with a water column model. The sediment model incorporates three processes: depositional flux of particulate organic matter (POM); diagenesis of POM; and the resulting sediment flux.

The model was calibrated to limited data collected between October 1996 and September 1997. Because of the relative scarcity of data, the model is only crudely calibrated at the present time. We will summarize the current state of the model application to southern Puget Sound, including results of the calibration to the existing data.

[1] Hamrick, J.M. 1994. Linking hydrodynamic and biogeochemical transport models for estuarine and coastal waters. Estuarine and Coastal Modeling. Proceedings of the 3rd International Conference. M.L. Spaulding et al Eds., American Society of Civil Engineers, NY, pp 591-608.

Characterization of Light Absorption by Particulate and Dissolved Substances Within Puget Sound

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Chlorophyll a, an indicator of phytoplankton biomass, exhibits large temporal and spatial variability within Puget Sound that is unresolved by most monitoring programs. The remote sensing of ocean spectral reflectance (color) provides a means to remotely assess surface chlorophyll concentrations and other water quality indicators which can complement existing monitoring efforts. The development of models relating ocean color to chlorophyll requires information on the relative contribution and variability of absorbing materials (e.g. chlorophyll, particulate detritus, dissolved materials) to the optical properties of Puget Sound waters. To address this question, we are measuring the spectral absorption characteristics of dissolved and particulate materials in water samples collected monthly as part of the Puget Sound Ambient Monitoring Program. We present seasonal trends in spectral absorption at various locations throughout Puget Sound, characterize the major light absorbing components and their relative contributions to seawater absorption, and describe their relationship with phytoplankton biomass.

Water Circulation And Fecal Coliform Budget of Dungeness Bay, Washington

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Fecal coliform concentrations have increased in portions of Dungeness Bay, resulting in commercial shellfish closures. Our study determined tidal circulation patterns, water and fecal coliform budgets. Sources of fecal coliform included the Dungeness River, harbor seals, seabirds, irrigation-ditches and shoreline septic system leakage. We used boats equipped with simultaneous GPS/depth sounder/CTDs to map bathymetry, circulation and water quality. Fecal coliform samples were collected at the mouth of the bay to determine inflow and outflow rates. Samples were also collected along drifter pathways to map coliform distribution and contribution by sea birds or seals and to generate estimates of coliform dieoff.

The Dungeness River was determined to be a major source of fecal coliform to the bay during the flood tide but not during the ebb when river flow was toward the Strait of Juan de Fuca. Harbor seals and birds were also important contributors. Irrigation ditches that periodically discharge to the bay had relatively low flow and often very high fecal coliform concentrations. A low-lying residential beach community located east of the bay is the type of area where septic system failure is common. However, the prevailing circulation in this area flowed away from the bay entrance, minimizing its fecal coliform contribution to Dungeness Bay.

POSTER GROUP G: MARINE BIOLOGY

The Burying Behavior of the Sepiolid Squid *Rossia pacifica*

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Sepiolid squids are known for burying in the sand during daylight hours but little is known of their burying behavior. Many live on subtidal deltas at the mouths of urban rivers so there is the chance of them burying in polluted sediments. Since burying squid are known for their bioturbation of sediments, the burying activity of the stubby squid, *Rossia pacifica*, was examined to determine how it buries, how it breathes while buried, how it sees while buried, and how it behaves under threats while buried. The squid buried themselves using a strict pattern with few deviations, thus indicating the behavior may be a modal action pattern. The squid formed a breathing hole while buried and probably formed a breathing chamber by consolidating substrate grains with mucus, which may be a primary use of its mucus. Under threat, it used water jets to emit “sand geysers” and ink “blobs.” Under repeated threats, it almost always emerged from the substrate, inked, and jetted into the water column. There is strong evidence presented here that *R. pacifica* may use an angling behavior while partially buried.

Where Have All the Sea Pens Gone? Or Vacant Benthic Habitats

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Golder Associates, Inc.

In 1968, Charles Birkeland documented an almost continuous band of the sea pen *Ptilosarcus gurneyi* around Central Puget Sound. This sea pen was described as a "key industry" species supporting a food web of eight predators. Further examples of dense beds of sea pens were described from additional locations in Puget Sound through the 1970s and 1980s. However, in recent years, once prolific sea pens have become scarce and have disappeared from areas once densely populated. With the sea pens have gone their predators. This disappearance of a once prolific assemblage has left vacant large areas of subtidal sand bottom benthic habitat in Central Puget Sound. With the decline of rockfish (*Sebastes* sp.) and other bottom fish, many benthic habitats have been left vacant. This study documents another vacant habitat.

Effects of Ultraviolet Radiation on Distribution of the Solitary Ascidian *Ciona savignyi*

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Western Washington University

Ciona savignyi is a solitary ascidian recently introduced to the Puget Sound. I tested the light sensitivity of this species to determine how it survives in fouling environments. I sampled field distributions to determine if a relationship exists between light levels, distribution, and health of *C. savignyi* adults. I exposed adults and embryos to natural sunlight partitioned by filters. Because eggs and embryos may have UV protection in their vitelline coat or follicle cells, I also demembranated eggs and exposed developing embryos to UV. In the field, no adults were found in sunlight exposed areas, but population densities were high in the shade. In shaded areas there was no relationship between adult length, UV light intensity and depth of the animals. The UV portion of natural light quickly killed adults, but embryos developed normally with UVB, UVA, and PAR portions of the spectrum. Demembranated embryos exposed to the full spectrum underwent embryogenesis suggesting that they have protection from UV. I suggest that *C. savignyi* colonizes docks through UV-protected embryos that may either disperse short distances or remain near the adults that spawned them. Information on the sensitivity, including damage thresholds, of ascidians and other fouling organisms to UV light is needed to understand their ecology and the structuring of the dock community.

The Pacific Sand Lance, *Ammodytes hexapterus*, in Puget Sound

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The Pacific sand lance, *Ammodytes*, is a widespread and ecologically important marine forage fish in Puget Sound. In spite of local abundance, little is known of its local biology and life history. Since 1989, WDFW investigators have been able to document the species' widespread use of upper intertidal fine-grained beaches for spawn deposition/incubation. At present, about 140 miles of Puget Sound shoreline have been found to be used by spawning sand lances. Spawning season is November-February. Some features of the sand lance's spawning behavior and spawning substrate grain-size spectra can be characterized. Upper intertidal spawn deposition/incubation makes the sand lance vulnerable to the effects of widespread shoreline armoring. All of its known spawning sites are currently protected by "no net loss" habitat management regulations. The propensity for the species to predictably use certain beaches each year for spawning should allow future investigators to collect important biological data not presently available for local Pacific sand lance populations.

Immunocompetence of Juvenile Chinook Salmon as a Function of Fish Size and Exposure to Dietary Polychlorinated Biphenyls (PCBs)

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Controlled laboratory challenges with *Listonella* (*Vibrio*) *anguillarum* were used to determine the effects of fish size (Study One) and oral exposure to PCBs (Study Two) on the immunocompetence of Puget Sound juvenile chinook salmon. In the first study, three subsets of fish (9, 20, and 39 grams per fish) were randomly allocated to tanks for one week acclimation prior to each challenge. Replicate groups were challenged at three concentrations of Vibrio bacteria (0, 1X, 10X) in either fresh or salt water, and monitored for 14 days. Smoltification status was assessed by monitoring plasma sodium levels prior to each challenge. In the second parallel study, groups of salmon were fed 4 levels of Aroclor 1254 for a period of 4 weeks. Following transfer and acclimation, half of the fish were challenged with Vibrio and monitored for 14 days. Subsequently, the other half was vaccinated (excluding

controls) and transferred to challenge tanks. Specific immunity was allowed to develop for 3 weeks prior to Vibrio challenge. Preliminary data indicate fish size may have had a small but significant effect on immunocompetence, but PCB exposure, even at relatively high levels, may not have had a significant effect on growth or survival following challenge

An Ecophysiological Study of the Effects of Hypoxia and Anoxia on Gelatinous Zooplankton of Southern Puget Sound

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We have examined the oxygen regulatory abilities and ability to tolerate anoxic conditions of several species of gelatinous zooplankton in the southern Puget Sound in order to estimate the effects of low oxygen on these ecologically important zooplankters. We have measured mean oxygen consumption rate, minimum oxygen partial pressure to which the organism can regulate O2 consumption (Pc) and the ability of each species to withstand anoxia. Our study includes ctenophores, scyphomedusae, hyromedusae, and siphonophores. It has been found that several species can oxyregulate at less than 15 percent oxygen saturation, as well as survive at 0 percent oxygen for several hours. The mean respiration rates for the scyphomedusa *Aurelia labiata*, the hydromedusa *Aequorea victoria,* and the ctenophore *Pleurobrachia bachei* were 0.18, 0.31, and 0.13 mmoles O2 g h-1, respectively. Additionally, *A. labiata*, *A victoria*, and *P. bachei* were able to regulate oxygen consumption below 10 percent saturation. These results indicate that gelatinous organisms are better at tolerating poor oxgyen conditions than many of their pelagic competitors and prey.

The Determination of Distinct Population Segments and Risk of Extinction for Puget Sound Populations of Pacific Herring and Brown, Quillback and Copper Rockfish through the Biological Review Team Process

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In response to a petition to list 18 species of marine fish in Puget Sound under the Endangered Species Act, the National Marine Fisheries Service initiated status reviews of seven of these species: Pacific hake, *Merluccius productus* (Ayres, 1855); Pacific cod, *Gadus macrocephalus* (Tilesius, 1810); walleye pollock, *Theragra chalcogramma* (Pallas, 1815); Pacific herring, *Clupea pallasi* (Valenciennes, 1847); brown rockfish, *Sebastes auriculatus* (Girard, 1854); copper rockfish, *S. caurinus* (Richardson, 1845); and quillback rockfish, *S. maliger* (Jordan and Gilbert, 1880). The National Marine Fisheries Service (NMFS) formed three Biological Review Teams (BRT), one for Pacific cod, walleye pollock and Pacific hake; another for copper, quillback and brown rockfish and the last for Pacific herring. These BRTs were composed of scientists with expertise in one or more of these species, to conduct these status reviews. This poster concerns the Copper, Quillback and Brown Rockfish and Pacific Herring Status Reviews that were recently completed. After considering available information on genetics, phylogeny and life history and environmental features that may promote reproductive isolation and local adaptation for these species, the rockfish BRT identified a "Puget Sound proper" Distinct Population Segment (DPS) for each of the three rockfish species. Other DPSs of each of the three rockfish may exist, however, it is not possible to define them given the available information. The Pacific Herring BRT identified a DPS that includes Puget Sound herring populations as part of the larger Georgia Basin DPS.

Various risk factors were identified for each DPS for the three rockfish species as well as Pacific herring. Major causes of risk include overharvesting, predation, regime shifts in the climate, habitat loss or degradation, and effects of pollution.

Conclusions of the biological status reviews have been reviewed by co-management agencies and have been transmitted to the NMFS Northwest Regional Office. Regional Office staff are preparing draft documents evaluating conservation measures and factors for decline. Final determination regarding possible listing proposals are pending.

Visual Development in Pacific Sand Lance, *Ammodytes hexapterus*

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For fish, the ability to successfully forage and avoid predators is dependent on visual abilities, particularly in the early life history stages. This study examined visual development in Pacific sand lance *(Ammodytes hexapterus*). Visual acuity, necessary for detecting prey at a distance, was measured by determining retinal cone density in fish 17 to 108 mm in length. Improvements in visual acuity were not rapid, indicating that highly acute vision is not a driving selective force in the feeding success and survival of the larvae. Spectral sensitivity, necessary for contrast perception, was measured using microspectrophotometry. Changes in spectral sensitivity indicated that early larvae, which typically inhabit surface

waters, are sensitive to blue, green, and violet light. Juvenile and adult fish, which have undergone a habitat shift to deeper waters, have lost sensitivity to violet light. By matching sensitivity to wavelengths commonly encountered in their photic environment, these fish experience improved contrast perception, facilitating detection of prey as well as predators. Sand lance are an abundant and, for many species, preferred forage fish in Puget Sound. Changes in their photic environment could lead to population declines, which would be felt throughout the food web.

POSTER GROUP H: NEARSHORE ECOLOGY

The Role of Salinity in Structuring the Aquatic Macroinvertebrate Community of a Puget Sound Oligohaline Lagoon

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The Foulweather Bluff Preserve (FWB) Lagoon, on Washington's Kitsap Peninsula, is recognized as a biologically significant site due to its brackish character. However, the lagoon is at the very lowest brackish water classification level (0.5 ppt)--highlighting the significance of the question, does salinity have a significant influence on the biota? Two macroinvertebrate collection methods were employed from August 1999 to October 2000 within the FWB lagoon, one freshwater pond, and two additional brackish lagoons (with maximum salinity values of 25.9 and 11.4 ppt). To date, laboratory analysis of macroinvertebrates has revealed an abundance of *Chlorohydra viridissima* within the FWB lagoon. Hydra have among the narrowest ranges of salinity tolerance of all invertebrates and *C. viridissima* has not been found in any of the other sites. Further analysis will determine whether this and other invertebrate distributions are a reflection of salinity or a response to some other physical factor or combination of factors. This information will serve as baseline information for the Nature Conservancy as they endeavor to preserve the FWB Lagoon, and as information for land use and environmental planners in their efforts to balance land uses and aquatic resources.

Eelgrass in Captivity: Population Dynamics in a Confined System

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An experimental stockpiling effort was initiated to determine the feasibility of growing eelgrass (*Zostera marina*) in flowing seawater tanks. The purpose of stockpiling is to 1) salvage plants that would otherwise be affected by development activities; 2) increase the population while in captivity; and 3) use the stock for restoration, thereby avoiding use of donor stock from undisturbed eelgrass beds. Initiated in the fall of 1997 with approximately 6,000 shoots, the population has stabilized over three growing seasons to the current size of 17,350 shoots. Population dynamics associated with growth in a contained mesocosm have resulted in both decreases and increases in population numbers over time. Initial population decline resulted from dense epiphytic growth on the leaf blades, macroalgae blooms shading the plants, plankton blooms reducing light availability, and mussel colonization on the plants. A population peak was reached in 1999, with nearly 30,000 shoots counted. We hypothesize that the tank has a carrying capacity that was exceeded in 1999, and the population has now stabilized to the current number. Further monitoring will validate this hypothesis and also help determine the effects of natural interannual variability on the population.

A Qualitative Comparison of Shoreline Biota in Central Puget Sound After 25 Years

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Coastal and Ocean Resources
Helen Berry, Betty Bookheim, and Amy Sewell
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Many shoreline sites in central Puget Sound inventoried in 1999 by DNR's Nearshore Program were previously sampled in the 1970s. We compared these datasets to examine long-term change in the biota of mixed-coarse (cobble-pebble-sand) beaches. While methodological differences preclude quantitative comparisons, general patterns emerge. Overall, the types and relative abundances of animals (epifauna and infauna) were quite similar among times. Some of these similar organisms include taxa ubiquitous in this common Puget Sound habitat type, but others comprised uncommon species present through time at the same few sites. Other organisms were dissimilar among times, many because of methodological differences (e.g., core depth, sieve size), others with no obvious explanation. There were no trends in the types of taxa (e.g., particular feeding modes) that changed through time, which might have suggested cause for concern. The only clear discontinuity between time periods was in the Point Wells/ Richmond area. Here, the 3 sites sampled in 1999 showed a striking reduction in abundance of taxa relative to 1970s surveys, and were

also different from beaches both to the north and the south in 1999. A variety of human impacts or physical changes could be responsible for this trend.

Seed Production of *Spartina anglica*, A Non-Native, Allopolyploid Cordgrass, Colonizing Intertidal Habitats Of Puget Sound, Washington

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Spartina anglica (Poaceae) is an invasive cordgrass that was introduced along Puget Sound in the early 1960s. Through rapid growth and sediment capture, this cordgrass is capable of effectively converting native intertidal habitats into *Spartina* marshes. *Spartina anglica* has colonized throughout central and northern Puget Sound via seed dispersal and the vegetative expansion of established clones. These life history traits allow *S. anglica* to disperse relatively easily and then rapidly spread throughout a habitat once seeds germinate. Despite the contribution of seeds to the colonization of *S. anglica* in Puget Sound, little is known regarding the amount and the viability of fertile spikelets produced by *S. anglica*. During the 2000 growing season, the maturation of *S. anglica* seeds was monitored in Puget Sound intertidal habitats. At each site, fertile culms were collected from separate clones and individually censused. From each inflorescence, total spikelets, fertile spikelets, percent fertile spikelets, sterile spikelets, and percent sterile spikelets were recorded. Seed viability also was measured. Results indicate that *S. anglica*, like other species of hybrid origin, produces a relatively small amount of mature, potentially viable seeds when compared to the total amount of spikelets produced per inflorescence.

Ongoing Invasion of the Asian Purple Varnish Clam, *Nuttallia obscurata*, into Puget Sound Waters: Does Anyone Care?

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Nuttallia obscurata is believed to have arrived in the Strait of Georgia region in ballast water in the late 1980s and was first collected in 1991, just north of the Canadian border. It spread very rapidly throughout the southern Strait of Georgia, but is moving more slowly south into Puget Sound. I have been studying this clam since late 1997, primarily in San Juan County, where it has become common in the upper mid intertidal - localized densities can exceed 500/m^2. It occurs in sediments ranging from cobbles to muddy sand, above (in tidal height) or near the native littleneck (*Protothaca*) and earlier-introduced Manila (*Venerupis*) and softshell (*Mya*) clams. *N. obscurata* is native to Japan, Korea, and perhaps China—its distribution is somewhat unclear because of historic taxonomic confusion among closely related species in Asia. It is not valued as a commercial species and apparently does not appear in markets in Japan, although it is eaten locally there. A map of its known occurrence throughout Puget Sound will be presented; most sites are north of Edmonds. It is also present on the outer coast in a few locations from Barkley Sound, Vancouver Island, to central Oregon.

Eelgrass Monitoring In Puget Sound: Methods and Preliminary Results of the Submerged Vegetation Monitoring Project

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Eelgrass *(Zostera marina)* is an important nearshore resource. In order to monitor changes in the abundance and distribution of this habitat type, the Nearshore Habitat component of the Puget Sound Ambient Monitoring Program initiated a Submerged Vegetation Monitoring Project. We are using a rotational random sampling plan with partial replacement. One fifth of the selected sample units are replaced each year, and once chosen, the unit is sampled for five consecutive years. We designated two types of sample units: 1,000 m sections of shoreline (potential 'fringe' eelgrass habitat) and eelgrass 'flats' (eelgrass beds wider than 1000 m). In summer 2000, we sampled 68 stations throughout Puget Sound including the Straits of Juan de Fuca. At each station we used underwater videography on a line transect to estimate eelgrass abundance, patchiness index, and average maximum and minimum depths. At 28 sites, we collected whole plant samples using a van Veen benthic grab to estimate shoot density, LAI, and shoot/root ratio. Data on the physical properties of the water column (temperature, salinity, DO, pH, turbidity, PAR, and backscatter) at each site can be linked to other data on stressors. The results show sound-wide patterns in overall abundance, density, subtidal extent and variability in eelgrass morphology.

Fish Distribution in Submerged Shallow Water Habitats Using Underwater Videography in Puget Sound

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Debra MacLellan and Randy Shuman
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In support of a King County Wastewater Treatment Division's Habitat Conservation Plan (HCP) and Marine Outfall Siting Study (MOSS), fish distribution data were collected from submerged shallow water habitats between Shilshole Bay Marina and Picnic Point using a towed underwater videography system. During this study, approximately 28 km of nearshore habitat were mapped between depths of +1 m and –30 m (mean lower low water) using side-scan sonar to delineate and map eelgrass and substrate types on georeferenced mosaics images. Underwater video footage was collected to ground-truth the sonar imagery and map the presence and location of fish, kelp beds, and benthic macroinvertebrates. The study generated approximately 144 km of georeferenced underwater video. GIS maps were developed for fish species and distribution. The fish distribution data was analyzed in relation to substrate type and eelgrass coverage. Fish species were categorized based on schooling and non-schooling behavior. The dominant species of schooling fish observed were shiner surfperch (*Cymatogaster aggregata*) whereas the dominant species of non-schooling fish were flatfish (Bothidae or Pleuronectidae) and ratfish (*Hydrolagus colliei*). Georeferenced underwater video provided a useful tool for understanding fish distribution and utilization of a variety of benthic habitats in eastern Puget Sound.

Statistical Trajectory Analysis of the Seeds of Common Cordgrass *(Spartina anglica)* in Northern Puget Sound

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Common cordgrass *(Spartina anglica)*, an invasive exotic, is a vigorous hybrid capable of competing with native saltmarsh vegetation, and colonizing intertidal mud and sand flats. From an innocuous 15 acres in 1979, *Spartina* has spread to 42 known location and covers over 600 solid acres as of 1997. The ability of *Spartina* seeds to colonize relatively distant sites makes a thorough survey and inventory of Puget Sound's extensive shoreline difficult.

The spread of the seeds of *Spartina* in northern Puget Sound was Statistically analyzed using two of NOAA/HAZMAT's spill models: OSSM (On-Scene Spill Model) and TAP II (Trajectory Analysis Planner). The objective was to generate probabilities that *Spartina* grass seeds originating from known colonies would beach in particular areas. This information could then be used to prioritize the treatment of *Spartina*, to locate possible new colonies of the grass, to backtrack new infestations to the parent colonies, and to quantify the environmental and cost savings from previously treated colonies. To generate statistics for this analysis, 15 years (1984-1998) of wind data, tide data and river flow data from numerous locations were used. For each known *Spartina* infestation a total of 500 model runs were randomly initiated spanning the months of October, November, and December between 1984 and 1998. Each run consisted of 1000 floating particles representing the seeds. To help determine where seeds would settle, shoreline segments were tagged with different beach types from the NOAA/HAZMAT Environmental Sensitivity Index (ESI) atlases to determine how quickly seeds would refloat once they came ashore. In addition, the shoreline of the modeled areas was segmented into about 1100 segments, and statistics were compiled on how these shoreline segments were impacted, including frequency, timing, and number of particles beaching. Computational runs utilized OSSM, and the data were displayed using TAP II. The result is a Windows and Macintosh application, TAP II, that shows the probability of where *Spartina* grass seeds would end up if dispersed from known infestation located throughout northern Puget Sound

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POSTER GROUP I: CONSERVATION AND RESTORATION

Preliminary Assessment of Marine Protected Areas for Rocky Reef Bottomfish in Skagit County, Washington—Skagit County Marine Resources Committee

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Skagit County Marine Resources Committee

The objectives of this project are to inform the public about rocky reef bottomfish and Marine Protected Area (MPA) issues and to solicit public comment and assistance on the establishment of MPAs in Skagit County. We will convene public meetings and partner group meetings to gather information on historical and current bottomfish catches in Skagit County and to determine the public's view on where to consider MPA locations. The public meetings are scheduled to start in November of 2000 and finish in February of 2001. Partner group meetings will likely be completed by this time. Preliminary results should be available for the conference. We intend to find if the public are interested in establishing MPAs in Skagit County in support of bottomfish recovery. We intend to determine the location of several rocky reef areas in Skagit County that have once or still do support bottomfish populations, based on public input, and that would be conducive to being established as MPAs. A summary report will be utilized to select several potential sites in Skagit County as MPAs and designate sites for further study.

Marine, Nearshore and Estuarine Conservation Targets for the Puget Trough/Georgia Basin Ecoregion:

Integrating the Marine Component of an Ecoregional Plan into a Geographic Information System (GIS)

Zach Ferdana
The Nature Conservancy

The marine, nearshore and estuarine environments of the Puget Trough/Georgia Basin - chiefly the Strait of Georgia, the Strait of Juan de Fuca, and Puget Sound - present an essential component of The Nature Conservancy's ecoregional planning process. Ecoregional planning entails identifying a set of sites that collectively capture viable examples of all native species and communities from among a larger set of planning units within the ecoregion. This collection of planning units, termed the "conservation portfolio," provides a systematic basis for site planning and acquisition.

The Nature Conservancy is currently working on the Willamette Valley/Puget Trough/Georgia Basin ecoregion to identify a portfolio of marine and terrestrial areas using an algorithm called SITES. For the marine component, this algorithm is incorporated into a GIS using information from various subtidal, nearshore and shoreline spatial data sets. Data gathering efforts by the State of Washington and the British Columbia Provincial government, as well as other partners, provide critical marine habitat information that help construct a framework for prioritizing sites at multiple scales across varying landscapes.

Our goal is to identify areas of significant biodiversity, highlighting elements such as communities and species that are rare, declining, or endemic within the larger ecosystem. SITES is an excellent analytical tool for designing conservation portfolios within a GIS, and presents a great opportunity to represent and protect the unique features of this region.

Transplantation and Alteration of Submarine Environment for Restoration of *Zostera marina* (Eelgrass): A Case Study at Curtis Wharf (Port Of Anacortes), Washington

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Using a blend of restoration techniques, we have altered the nearshore zone on the southern side of Guemes Channel such that an in situ eelgrass (*Zostera marina*) patch has expanded (rhizomal) and new patches are forming (seed dispersal). Our project was initiated to mitigate the effect of dock shading by the joining of two adjacent commercial docks. In response to the requirement by the Washington State Department of Fish Wildlife, we concluded that the results of a blend of small-scale, low-cost, restoration techniques to enhance the eelgrass zone immediately adjacent to the project would meet protection goals. Our plan required that 1) historically deposited rubble and debris (e.g., concrete blocks, wire cables, metal fencing and rubber hose) be removed from the eelgrass zone; 2) a section of dock which shaded the benthos be removed; 3) reflective panels be installed to alter submarine light under existing dock; 4) eelgrass plants from the proposed construction area be transplanted to debris-free site; and 5) changes in eelgrass cover be monitored over three years. We recommend that this approach be considered at other sites in the Puget Sound Basin.

Can Eelgrass Transplanting Work? Two Small Victories for the Grass

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The reported history of success of eelgrass transplanting in the Puget Sound area has been checkered at best. Two examples of successful eelgrass transplantings are reported. In a small-scale prototype transplant on an exposed sandy beach, estimated number of shoots had multiplied by 100 times over 2 years and the eelgrass patch was indistinguishable from a nearby reference patch. In another experiment in Port Angeles, a cap of inorganic sand was placed over a 1,500-ft^2 area with thick wood debris from years of log raft storage. The cap was planted with 429 planting units (PU - 3 eelgrass shoots and associated rhizomes). About 40 percent of initial PU remained after two years and new shoots had radiated an average of 7 to 12 inches around the surviving PU. In 2000, no significant differences in blade length, rhizome spreading, or shoot density were seen between fertilized and unfertilized areas in the bed. However, PUs with longer blade lengths (12 inches) at the time of planting had significantly longer blade lengths than those PUs clipped shorter (to 7 inches). Sediment organic carbon increased from 0 at the time of capping to about 0.2 percent in 1999 and 2000.

Value of Integrated Management Approach to Sustainability as Demonstrated in Carkeek Park and the Pipers Creek Watershed

George Selkirk
Selkirk Miller Hayashi Architects
Gavin Patterson
Seattle Public Utilities
Nancy Malmgren
Carkeek Watershed Community Action Project

Agencies and community people in urban Seattle have partnered in the development of an integrated demonstration model at Carkeek Park and the Pipers Creek (Carkeek) Watershed for over twenty years to achieve clean water and a sustained salmon run. They have achieved many successes in the restoration of habitat in the park and the community culminating in the restoration of the salmon run in the creek system. This partnership has now launched into the first step in improving the educational component by remodeling the Annex of their Environmental Education Center to have a demonstration "green" building on the Carkeek Park Education Campus. Learn how the "New Urban Creek" restoration, the Salmon Friendly Garden and backyard Habitat Gardens, and how the remodeled "green" building can enhance and benefit the earth's sustainability.

The Piper's Creek Erosion and Sedimentation Control Project is part of an integrated approach to mitigating the negative effects associated with urban creeks. It installed in-stream features to enhance the variety of habitat and addressed serious street runoff erosion on the steep hillsides.

The goal of the remodeled Annex is to achieve Platinum rating in the LEED Green Building Rating System. As they pertain to salmon habitat, the methods of construction, choice of materials, energy conservation, and management of waste and storm water will be the primary sustainable features of the building.

Sustainable Design for the Urban Coastline: A Case Study

Sunita Nanda, Sandy Wyllie-Echeverria, Marina Alberti, and Marc Hershman
University of Washington

Much of coastal development has proceeded by relying on design schemes that stop at the water's edge. This approach neglects the natural processes that operate at the land/sea interface and often results in a degraded submarine environment, loss of valuable fish and waterbird habitat, and recreational uses incompatible with the site. We propose a conceptual model for a coastal park area that integrates upland and marine landscapes and ecological functions, with state and regional policy objectives to preserve habitat, and water dependent recreational activities. This project, developed for a regional port authority, addresses the need for a comprehensive, long-term, planning strategy to effectively integrate the human and ecological functions of the port. The conceptual model visually represents interactions between humans and coastal and submarine landscapes, identifies areas suitable for the restoration and enhancement of submerged and shoreline habitats and provides opportunities for use of the site in regional educational programs. We recommend that this design exercise be considered at other sites in the Puget Sound Basin, as a more sustainable model for development within an urban coastal zone.

The Orca Pass International Stewardship Area: Hands Across the Border

Mike Sato
People for Puget Sound

Despite the political boundary, the "transboundary" waters between BC and Washington State are really a single ecosystem. In the fall of 1999, more than twenty citizen groups came together around the need to establish a protected area in these shared waters. The area is rich in natural beauty, marine biodiversity, environmentally sensitive habitat, and sites of cultural and spiritual importance to Coast Salish tribes and First Nations on both sides of the border. The area that's being proposed includes and adjoins Boundary Pass (between the Canadian Gulf Islands and the US San Juan Islands), and it has been dubbed the "Orca Pass International Stewardship Area" (after the Orcas that transit these waters regularly). The area was selected after GIS mapping of marine resources, consideration of constituent interests, and meetings with government officials on both sides of the border to look at how this citizens' initiative could complement and enhance related efforts such as the Islands Trust/San Juan County marine protection initiative and the National Marine Conservation Area proposed by Parks Canada for southern Georgia Strait.

A Nearshore Substrate Enhancement Project in Elliott Bay, Washington

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King County Department of Natural Resources
Patrick Cagney
U.S. Army Corps of Engineers
Margaret Duncan
The Suquamish Tribe Fisheries Department

A nearshore subtidal enhancement project was initiated in March 1998 near Duwamish Head in Elliott Bay, Washington to increase habitat diversity for marine organisms by introducing approximately 60 cubic yards of material. The project was undertaken jointly by the Elliott Bay/Duwamish Restoration Panel, comprising federal, tribal, state, and local agencies, to address natural resource damages in Elliott Bay, and the U.S. Army Corps of Engineers.

Substrate material, placed at –4 to –12 ft. and at –35 ft. MLLW, consisted of pea gravel and oyster shell (one plot each), quarry spall and cobble (3 plots each). The specific materials were placed in the 8 plots at 2 sites with a maximum height of 18 inches. The five year monitoring program to assess macroalgae and invertebrate colonization includes physical observation, biological sampling and video documentation.

Monitoring through August 2000 demonstrates that the cobble and spall substrates are effective for increasing macroalgae and providing cover for fish and invertebrates. Epibenthic invertebrate surveys conducted at the pea gravel plot show an increase in juvenile salmonid prey. The oyster shell shows red rock crab and shore crab recruitment.

POSTER GROUP J: MARINE RESOURCES

Virtual Transects: A Novel Technique for Assessing the Linear Extent of Floating Kelp Beds in Washington State

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Kelp bed abundance is usually quantified by areal measurements, which are easy to derive from Geographic Information System (GIS) data. However, kelp beds can also be viewed as a feature that is distributed in a linear band along the shore. The characterization of kelp beds as an along-shore feature may be as important as kelp bed area for assessing habitat function. We have developed a novel technique to determine the spatial distribution and abundance of floating kelp as a linear feature. The input data are a vector shoreline and kelp canopy polygons derived from remote-sensing data. The algorithms are written in the C++ programming language. First, the shoreline vertices are densified to 10 meters. This densification value was selected based on a minimum kelp patch size of 40 meters diameter. Next, for each point on the coastline, a 'virtual' transect is extended a specified distance from shore. If this transect intersects a kelp bed, the originating point is assigned a code to indicate that kelp was found offshore. We calculate the length or proportion of shoreline that has kelp offshore, and delineate the spatial distribution and extent of kelp

beds along the coastline. Our approach is quite robust to changes in input shoreline resolution as well as variations in methods for determining transect angle. We will compare this linear measure of kelp habitat abundance to areal abundance measures, especially how these measures describe trends over time. Finally, this technique could be used to estimate the abundance of any feature that tends to be distributed linearly along a feature such as coastline or river.

Geologic Mapping of Marine Benthic Habitats at Puget Sound, Washington

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U.S. Geological Survey
Wayne Palsson
Washington State Department of Fish and Wildlife
Gary Greene
Moss Landing Marine Lab
David Mosher
Geological Survey of Canada
Greg Baker
National Oceanic and Atmospheric Administration
Peter Dartnell, Guy Gelfenbaum, and Christopher Sherwood
U. S. Geological Survey

Seafloor morphology and substrate type are two primary physical factors that define marine habitats. Despite many years of study, the nearshore areas of Puget Sound remain largely unknown because of their great extent, difficulty of direct observation, and geologic heterogeneity. Recent advances in marine-survey technology, like acoustic and laser bathymetric systems, now provide detailed imagery that help determine the geographic distribution of benthic habitats. High-resolution mapping, coupled with well designed geologic and biologic sampling, enable researchers to evaluate ecosystem character and extent on regional and site-specific scales. Such evaluations are central to the delineation and management of Marine Protected Areas. These data also support: 1) the development of circulation models, which are critical to identifying pathways for the movement of sediment, nutrients, and biota, and 2) understanding the response of nearshore environments to dam removal. Examples of seafloor-mapping techniques are presented to demonstrate their utility for ecosystem research. Coordinated efforts by marine geologists and biologists are required to translate the high-resolution imagery into readily useable maps that accurately depict both seafloor geology and biology, and meet the needs of habitat researchers.

An Inventory of Washington State's Marine Shorelines using the ShoreZone Mapping System

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Washington State Department of Natural Resources
John Harper
Coastal and Ocean Resources

Accurate information on the quality, quantity and distribution of intertidal habitats is important to monitoring and sustaining the health of Puget Sound. The Nearshore Habitat Program of the Department of Natural Resources (DNR) inventories and monitors intertidal habitats as part of the Puget Sound Ambient Monitoring Program. The crucial need for a rapid and consistent inventory of more than 3000 miles of shoreline has led to the completion and distribution of Washington State's ShoreZone Mapping Project.

This poster summarizes the state-wide inventory of Washington's marine shorelines using the ShoreZone Mapping System. This helicopter-based method uses videography with simultaneous audio descriptions by both a coastal geomorphologist and marine biologist. The data were collected between 1995 and June 2000. The resulting GIS data set includes approximately 50 parameters that describe important physical, anthropogenic, and biological shoreline features. Inventory results show spatial patterns in features that are considered by many to be indicators of ecosystem health. The digital data set is available on CD-ROM.

Building a Seamless Digital Elevation Model of the Puget Sound Basin

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U.S. Geological Survey
Harvey Greenberg
University of Washington

The digital elevation model (DEM) of Puget Sound forms the fundamental topographic description of the region from which most, if not all other, geographic information system (GIS) products are derived. Yet for both historic and jurisdictional reasons, DEMs are truncated at Mean Sea Level, making it impossible to model shore and estuary environments in a GIS. The traditional boundary between land and sea governing agencies complicates the integration of bathymetry and topography because there is a general lack of data overlap at the shoreline and because the elevation products of the NOS and the USGS are developed in two incompatible vertical datums.

We attempt to rectify the vertical datum differences between NOS hydrographic survey data (Mean Lower Low Water) and the USGS 10 meter DEM (NGVD1929) by constructing a correction surface from over 80 tide stations throughout Puget Sound. From the correction surface, we have attributed the DNR shoreline with Mean High Water elevations and use this to re-interpolate the near-shore topography between the NOS bathymetry and the published USGS contours. The resulting DEM reveals limitations in the density of near-shore elevation data, particularly in deltaic environments, but it provides a seamless digital model of the Puget Sound Basin which is uninhibited by artificial boundaries between land and sea.

The Shoreline/Coastal Planners Group: Linking Science to Puget Sound Shorelines Management

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Washington Sea Grant Program
Douglas J. Canning
Washington State Department of Ecology

Objective: To deliver current, accurate science-based tools and information relevant to the planning and management of Puget Sound's marine and coastal resources to local government shoreline planners and resource managers.

General Methodology: Formal biennial needs assessment surveys of local shoreline planners in Western Washington are used to identify topics continuing professional development. Topic clusters include *shoreline resources (e.g. nearshore habitat monitoring), shoreline land and water uses (e.g. port development), shoreline management administration (e.g. conditional use permit processing), or information technology (e.g. GIS applications)*. Preferred meeting times, duration, frequency and style are similarly determined. Science and policy experts from universities, agencies, NGOs and the consulting industry invited to present at CPG meetings are briefed on the audience characteristics, their level of scientific literacy and efficacious presentation styles.

Results: The Shoreline/Coastal Planners Group meets quarterly at rotating locations around Puget Sound and Coastal Washington with topics selected to have relevance in each locale. Single three-quarter day meetings facilitate travel and eliminate overnight lodging expenses. Attendance has grown steadily since 1993 as organizers fine-tuned the meeting design. Average attendance is approximately 45 with a range of 30-80, depending on topic and location.

Significant Conclusions: Despite heavy work loads and regional transportation congestion, local shoreline planners will participate in continuing professional development programs which meet local needs for science-based tools and information.

Practical Applications: Non-formal client-based education and training programs such as the CPG could be applied to other Puget Sound management programs and institutions, including watersheds and marine water quality.

Examples of Application of ShoreZone Mapping Data from the State of Washington

John Harper
Coastal and Ocean Resources
Helen Berry
Washington State Department of Natural Resources

The ShoreZone Inventory of Washington includes detailed characterization of approximately 5,000 km of shoreline between the Columbia River mouth and the Canadian border. The data set is suitable for a wide variety of applications including state-wide and regional land-use planning, scientific research and tactical planning for oil spills. This paper provides examples of how the data set can be used.

- Regional summaries of resource distribution can guide protection and restoration. The inventory shows a state-wide occurrence of eelgrass on 30 percent of the state's shoreline, with occurrence as high as 60 percent in northeast Puget Sound and less than 13 percent in southern Puget Sound.
- The ShoreZone Inventory can be combined with freshwater habitat data from the Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP) to produce a more complete profile of the habitats used by salmonids.
- Biophysical data can be used to select and screen potential monitoring sites. Narrow sand & gravel beaches are the most common shore type in Puget Sound, making them a candidate for monitoring. The data set identifies the location of these sites.
- Predetermined models such as potential oil residence can be used to prioritize oil spill response. In King County, 13 percent of the shoreline has the highest predicted oil residence time.

Status Review of Chum Salmon for ESA Listing in Puget Sound

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National Marine Fisheries Service

In 1994, the Northwest Region of the NMFS received petitions to list chum salmon (Oncorhynchus keta) from Puget Sound as threatened or endangered species under the Endangered Species Act (ESA). In response to these petitions and the more general concerns for the status of

Pacific salmon throughout the region, NMFS initiated biological status reviews for all species of anadromous salmonids in the Pacific Northwest. In December 1997 the NMFS Northwest Fisheries Science Center published a status review from the Chum Salmon Biological Review Team (BRT) that described four distinct population segments or evolutionarily significant units (ESUs) of chum salmon: Strait of Georgia/Puget Sound Hood Canal Summer-Run, Pacific Coast, and Columbia River. The BRT reviewed population abundance data and other risk factors for these ESUs and concluded that two (Hood Canal Summer-Rum and Columbia River) were likely to become endangered in the foreseeable future. In 1999 summer chum salmon in Hood Canal were listed as threatened under the ESA.

This presentation summarizes both the original information from the1997 chum salmon status review, and new information on the Hood Canal Summer-Run and Columbia River ESUs received since the listing in the federal register notice.

Potential Impacts of Cascadia-margin Earthquakes on the Fraser (Vancouver) and Duwamish Deltas (Seattle)

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Patrick Monahan
Monahan Petroleum Consulting
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Large earthquakes generated along the Cascadia subduction zone pose hazards to greater Vancouver and Seattle, whose ports are built on the Fraser and Duwamish River deltas, respectively. Although located more than 100 km from the outer coast, the cities remain at risk due to local conditions that increase the potential of earthquake-induced ground failure. The accumulations of loosely consolidated delta sediment are up to 300 m thick and can significantly amplify ground motions. Dynamic motions with site periods vary from 0.2 to 0.5 seconds on the delta margins to 4 seconds in the delta center.

Extensive drilling programs by the USGS, GSC, and other agencies recently have examined the sedimentary framework of these urbanized deltas. The primary objectives were to determine the stratigraphic and geographic distribution of sandy sediment, which is susceptible to liquefaction, and to evaluate the potential impact of earthquakes on the region's industrial and transportation infrastructure. Sand-filled dikes, sills and other paleo-liquefaction features are commonly visually observed and suggest the occurrence of strong ground shaking in the past. Cone-penetration tests (CPT) and standard penetration tests (SPT) were used to characterize potentially liquefiable deposits. The sandy unit of principal concern on the Fraser delta is 8-30 m thick and interpreted to represent a complex of distributary channel sands. The youngest and most liquefiable deposits are located adjacent to the present Main Channel and delta front. Buried channels and laterally continuous layers of sand, probably derived from lahars (volcanic debris flows), also occur on the Duwamish delta. Based on modeled earthquakes, where ground acceleration may significantly exceed 0.2 g, there is a high potential for large strain disintegrative flow failure on the delta front and slope, potentially including the port facilities.

A Wide Area Rapid Assessment Technique for Benthic Habitats

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Golder Associates, Inc.

Offshore geophysical survey methods provide a rapid and cost-effective tool for environmental assessment of coastal zones, estuaries, rivers, lakes, and other water bodies. Mapping of benthic habitat and subsurface geology by Golder Associates Inc. (Golder), is done from small vessels using an integrated combination of side-scan sonars, single or multibeam echosounders, subbottom profilers, underwater video, and the differential global positioning system (DGPS). Surveys conducted to map submerged aquatic vegetation (SAV) (*Zostera* sp. and macroalgae) using solely underwater video can miss important features such as abandoned outfalls, partially buried cables, recreational vessel mooring anchors, and rock outcrops. In addition, video surveys will misrepresent patchy eelgrass conditions as contiguous beds causing erroneous estimates of areal coverage and habitat value. This can cause problems with alignment and site selection and impact mitigation planning. A side-scan sonar survey, integrated with video images to verify species composition and signal interpretation and real-time DGPS for precise positioning, provides a comprehensive high-resolution map of actual conditions over a relatively large area. Data acquisition and post-processing to produce a map of surficial conditions requires considerably less time and effort compared to mapping the same area by scuba diver or with underwater video alone. This poster presents results from recent marine geophysical surveys conducted to map and select a route for a proposed fiber optic cable in the San Juan Archipelago, Washington.

Submarine Landslides in Northern Puget Sound: Magnetic Susceptibility Analysis of Piston Cores Collected Near Edmonds, Washington

Linda C. Miller and Dr. Mark L. Holmes
University of Washington

High resolution seismic reflection data suggest that the uppermost 150-200 m of post-glacial sedimentary fill beneath Puget Sound consists primarily of turbidite and landslide deposits. The objectives of this study were a) to obtain long (~10 m) piston cores that would penetrate deeply enough to return samples of the most recent turbidite/landslide deposits and b) to determine the geometry and relative ages of the deposits and their frequency of occurrence. Digital bathymetry data from NOAA were used to select a general study area in the vicinity of Edmonds. Site surveys were conducted using a 3.5 kHz subbottom profiler aboard the University's *R/V Thomas G. Thompson*. Four long (4-9 m) cores were obtained from a variety of morphological provinces extending from Point Wells to the Meadowdale area. Two thick (0.7 and 1.2 m) turbidite sequences from a core 2.5 km north of Edmonds indicate that the shoreline has been unstable during the last 1000 yrs. Understanding the various mechanisms by which the shores of Puget Sound are undergoing continuous modification is important if we are to safely engage in the types of offshore engineering and development – sewer outfalls, port facilities, etc. – that the area's growing population will demand.

Trends and Distribution of Marine Debris in Puget Sound: What's Thrown in, Stays There

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Washington State Department of Fish and Wildlife

A variety of laws exist that prohibits the intentional discarding of debris in nearshore environments like Puget Sound. Despite these laws and due to accidental releases, many forms of debris enter the marine environment and accumulate on the bottom. Since 1989, the Washington State Department of Fish and Wildlife has identified and weighed benthic debris collected during trawl surveys for groundfish and during PSAMP fish surveys. Debris was categorized and weighed as glass, aluminum, plastic, fishing gear, and other. Catch rates and densities of these debris categories were mapped and were used with the area-swept technique to estimate the amount of benthic debris within Puget Sound.

Benthic debris was most common in or near urbanized areas, and debris estimates were the highest from South and Central Puget Sound near Tacoma and Seattle. Total debris estimates ranged from 120 mt to over 630 mt for most areas of Puget Sound exclusive of the San Juan Archipelago which was not surveyed. Glass bottles were the most frequent category of marine debris encountered, but large tires also accounted for a substantial portion of debris. Fishing gear was also encountered in the form of derelict shellfish pots, especially in Hood Canal. While trends vary by region and may be influenced by relative sampling effort, there appears to be an increasing trend in the amount of benthic debris in Puget Sound.

Pen-raised Fish Attract Orca Whales: An Hypothesis Concerning an Extended Stay of Orca Whales in Dyes Inlet in 1997

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Orca whales (*Orcinus orca*), resident of waters of the San Juan Islands, Washington, feed primarily on salmon and are occasionally seen in Puget Sound individually or in small groups. In October, 1997, three pods totaling 58 whales appeared in Dyes Inlet. After one day all but 19 Orcas left. These remaining animals stayed an additional 29 days. During this time, it is assumed that the Orcas fed on the Chico Creek Chum salmon (*Oncorhynchus keta*) run. The food requirement for these Orcas was calculated by multiplying the total weight of the 19 animals (mass approximately 56,700 kg) by a daily consumption of 5 percent of their body weight. Based on this estimate, the 19 Orcas would have required 82,215 kg of fish during the 29 days they were in Dyes Inlet. Predicting the Chico Creek 1997 chum run (escapement 4,328 fish) as its historical percentage of Area 10E indicated a shortfall of approximately 63,000 kg between available salmon and the Orca's requirements. We suggest that the Orcas in Dyes Inlet fed on Atlantic salmon (*Salmo salar*) escaped from a pen farm nearby which spilled between 369,000 and 400,000 fish (1,079,325 and 1,170,000 kg) three months earlier.

REEF—A Volunteer Fish Monitoring Program in the Pacific Northwest

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Reef Environmental Education Foundation

The REEF Fish Survey Project is a volunteer fish-monitoring program developed by the Reef Environmental Education Foundation (REEF). REEF volunteers collect fish distribution and abundance data using a standardized visual method during regular diving activities. Survey data are recorded on preprinted data sheets that are returned to REEF and optically digitized. These data are housed in a database that is publicly accessible on REEF's Website (http://www.reef.org).

Since its inception in 1993 the REEF program has generated over 25,000 surveys in the Caribbean region. In 1998 REEF expanded to the Pacific Northwest and to date, over 450 surveys have been conducted throughout Puget Sound, the San Juan Islands, and British Columbia. Through a partnership with the Living Oceans Society, a pilot study is currently underway to include invertebrates in the Pacific Northwest REEF methodology. REEF's standardized census method provides a consistency in data collection applied over a wide geographic range. The REEF database represents a valuable tool for marine resource managers and scientists. The database establishes baseline data, provides a taxonomic inventory, and can be used to develop species distribution maps and examine species and community trends. REEF data are currently being used for a variety of assessment and long-term monitoring projects.